MECHANICAL DRAWING

DeWitt Hunt

Mechanical Drawing

By

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PREFACE

This text book has been planned on a dual outline. The first purpose has been to present drawing problems in a practical sequence, proceeding from the very easy to the easy, and from the easy, working very gradually, toward the difficult and the more difficult. The second purpose has been to present the informational material of mechanical drawing in a slowly developing regularity. These two aims are imperfectly realized by listing the number of drawing problems likely to be completed in the public school drawing course, and grouping the instructional material or subject-matter around these problems. All models used as drawing problems have been selected because they suit the ability of the student at that time, and because the drawing of that particular model teaches the subject-matter under consideration in that stage of progression, in the series of drawing problems.

In the assignments in this text, the student has several drawings to copy, several to complete by making the second or third view, several to make from oblique projections and several to make from dimensioned photographs. Besides these, several written descriptions are given, together with a number of outside research assignments. In addition to these types of problems, the drawing teacher should provide as many actual models, such as the U. S. Machine Bolt, a Square Thread problem, several Packing Glands, a Globe Valve, etc., so that the student may secure experience in drawing from models. Projection screens similar to those in Chapter I should be provided as a part of the regular equipment of the drawing room.

The order of assignment of drawing problems may and should be varied to suit local needs as are discovered by the drawing teachers. In some instances, problems covered in separate chapters may be included in a single drawing. Inking may be delayed until after an entire semester or a full year has been spent in making pencil drawings. Lower case

letters should not be presented until the student can easily master them, upper case letters being used exclusively prior to that time. Other variations from the progressions in this text should be made at the desire of the teacher.

ACKNOWLEDGMENTS

Much credit is due and an expression of appreciation is hereby made to The Eugene Deitzgen Company for furnishing the cuts for Figures 7, 8, 11, 12, 13, 18, 18a, 19, 21, 23, 24, 25, 26, 27, 28, 30, 40, 43, 45, 46, 46a, 48, 59, 63, 68, 70, 73, 74, 81, 107, 114, and 146. The effectiveness of this book would be greatly reduced without the use of these fine illustrations. An expression of appreciation is also made to The House and Garden Magazine for the use of Figure 75 which was reproduced from their copy; to The American Builder Magazine for Figure 131 which was taken from their magazine; to The Southern Pine Association for the privilege of making Plates XXII and XXIII from their book of garage plans; to The Briggs Lumber Company, publishers of The Builder Magazine, from which the copy for Figure 133 was taken; to the Link-Belt Company for furnishing cuts for Figures 82 and 83; to the E. H. Sheldon Company for the use of cuts for Fignres 167 and 168; to Mr. L. K. Anderson who made the copy for Plate I; and to The American Face Brick Association for furnishing cuts for Figures 130 and 132.

Many of the line drawings in this Book were made by Mr. Henry G. Adams, who has been a student in my classes during the time this book has been in preparation, and an expression of appreciation to him is hereby made.

De Witt Hunt

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Mechanical Drawing

CHAPTER I.

The Theory of Mechanical Drawing

A mechanical drawing is a drawing made with instruments in which all of the lines of an object are shown in their true relations of length, position and direction.

The purpose of all mechanical drawings is to so represent an object that the size and shape conceptions are definite in the mind of the observer. Most mechanical drawings serve only one purpose: to represent the object in such a way, that it may be made from the drawing. A photograph or a perspective drawing does not always convey true size and shape impressions to the person viewing the same.

All solids are bounded by points, lines, and planes. A cube has six equal planes, eight equal lines, and eight points. To attempt to represent the different planes of the cube would require shades or colors. An isometric drawing of the cube would show three faces. A photograph may show three faces as a maximum. These faces show in shades or shadows. The extent of any plane is indicated by lines; so that an object may best be represented by representing the lines of it. The following definition of lines may be of assistance:

A straight line is the shortest distance between two points.

A line is the path of a moving point.

A line is formed by the intersection of two planes.

All intersections of planes on the surface of an object form lines. All of the lines of an object must be shown in all of their relations. Lines have three comparisons or relations: 1st, length; one line may be shorter or longer than another; 2nd, direction; two lines may run parallel or at right angles

to each other; 3rd, position; one line may be above or below the other, the relative position affords a comparison of lines. Thus a drawing which shows the true relation of all of the lines of an object will give all necessary details, so that the object can be reproduced from the drawing, which, after all, is the chief purpose of the mechanical drawing.

"A working drawing is one, from which the object drawn, may be made." This drawing must have all dimensions expressed and must show all materials.

Mechanical drawing theory is based largely on conventionalities and assumptions. It is not an exact science like geometry, but after setting up many conditions, certain problems of geometery are often applied. The general explanation of mechanical drawing assumes that space is divided into four quadrants by two intersecting planes, a horizontal or H plane, and a vertical or V plane. The angles or quadrants are numbered 1, 2, 3, and 4, beginning with

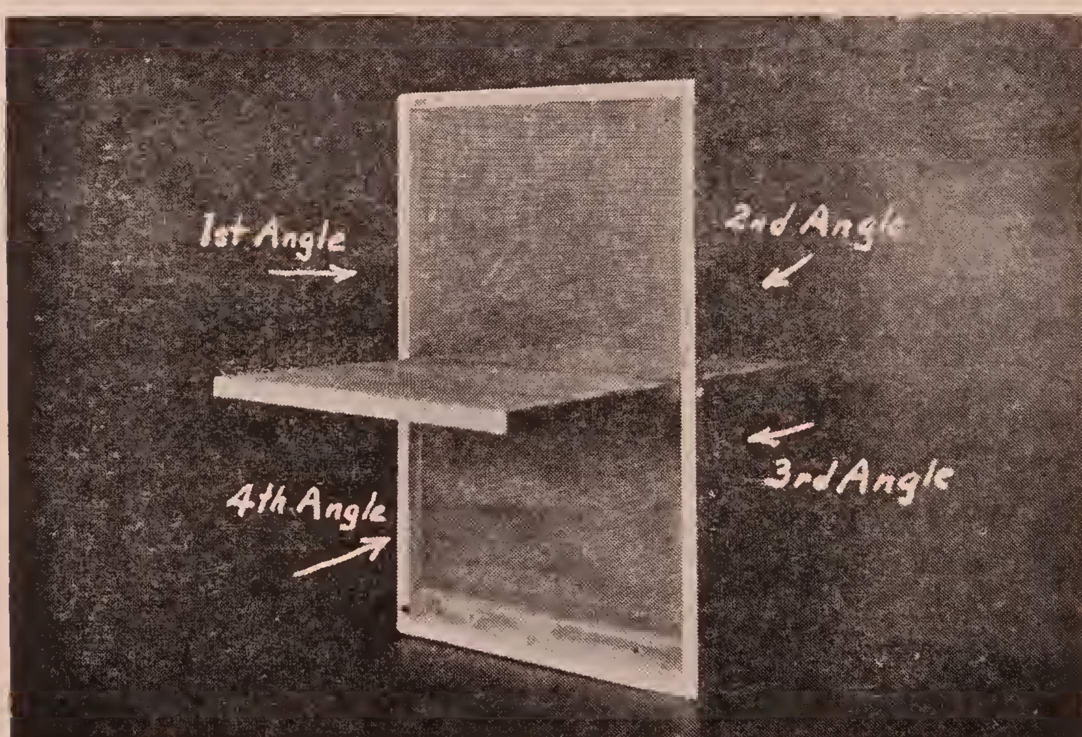


Fig. 1. The H and V planes of projection.

the top front angle and progressing clockwise when viewed from the right end. (See Figure 1.)

An object, when placed in either quadrant will project its outline on each of these planes. These outlines become the views of the object when the H plane is revolved about the line of intersection so that quadrants 2 and 4 are reduced to zero degrees, and the H plane coincides with the V plane. The method followed in the United States is to assume that the object is always placed in the third angle. Thus the top projection is found in the H plane and the front projection is found in the V plane. When the H plane is revolved, the H projection or view is turned into a plane coinciding with the V plane. The line of intersection and revolution is called the ground line, (G. L.) and is drawn in the actual representation of these planes. Everything above the ground line becomes the H projection and everything below the ground line becomes the V projection. (See Figure 2).

Several rules are readily formulated from these hypotheses. Some rules governing points are as follows: Consider points in the third quadrant.

1. *The H projection of a point is as far above the G. L. as the point is back of V.*

2. *The V projection of a point is as far below the G. L. as the point is below H.*

3. *The two projections of a point always lie in a line perpendicular to the G. L.*

4. *The distance between the H projection of two points is always the same as the distance between the V projections of these two points when measured on any line parallel to the G. L.*

When an object is placed in the third quadrant its projections are drawn on the H and V planes, the H plane is then folded up into the V plane and the H projection becomes the top view of the object and the V projection becomes the front view. By eliminating the G. L. we have the

ordinary conception of the top and front views of a working drawing. (See Figure 2.)

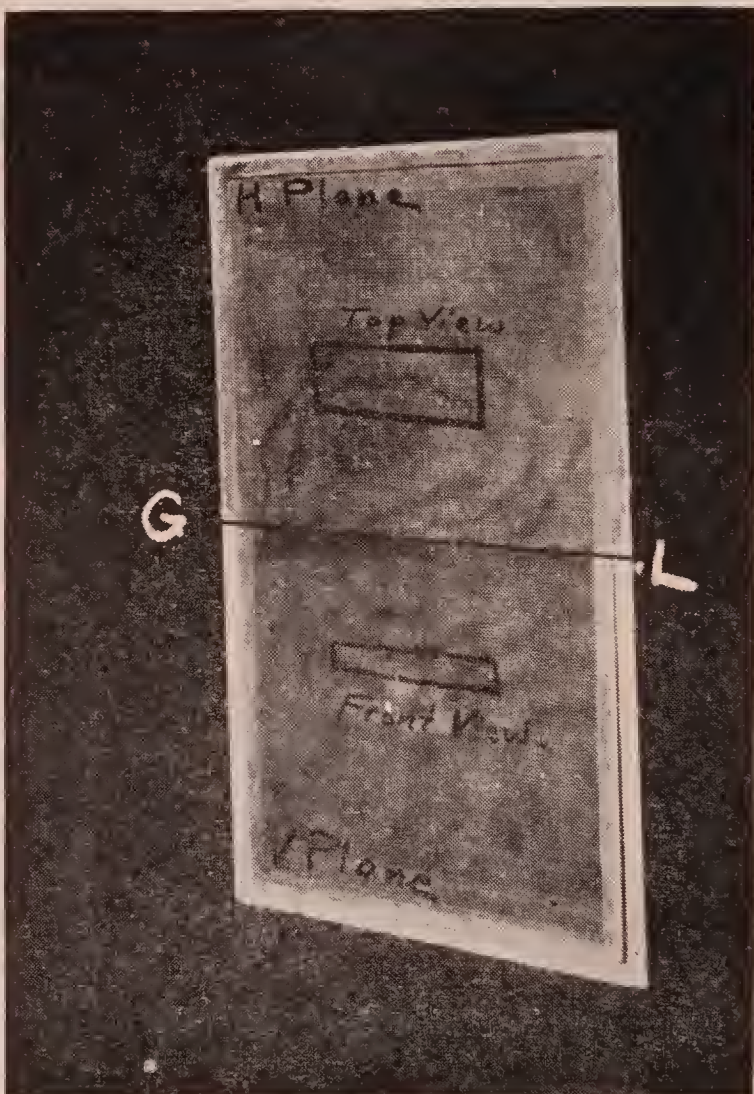


Fig. 2. The object in the third quadrant and its projections on the H and V planes.

This plan, so far, has not provided for a third view. A third or profile plane perpendicular to the G. L. is passed to the right of the object and through these two planes. This affords a plane on which the end view of the object may be projected. By agreeing on the use of the third quadrant, and eliminating all extra planes, we have a box-like

set of three planes. (See Figure 3.) The object is placed under the H plane, back of the V plane and to the left of the "profile" plane; the three projections are then obtained. After the projections are recorded, the H plane is folded up into the V plane and the profile plane is revolved into line with the V plane, using its line of intersection with the V plane as an axis. (See Figure 4.) The three views are then in these relative positions:

Fig. 3. The Projection box for finding three views of an object.

The top view is directly over the front view.

The right view is directly to the right of the front view.

Also these results are apparent:

All lengths are the same in the top and front views.

All heights are the same in the front and right views.

All widths are the same in the top and right views.

The left edge of the right view is the front of the object.

The lower edge of the top view is the front of the object.

Thus, the representation of the object is a series of projections of the object or of the lines of the object on planes. In some cases the detail of some oblique surfaces of the ob-

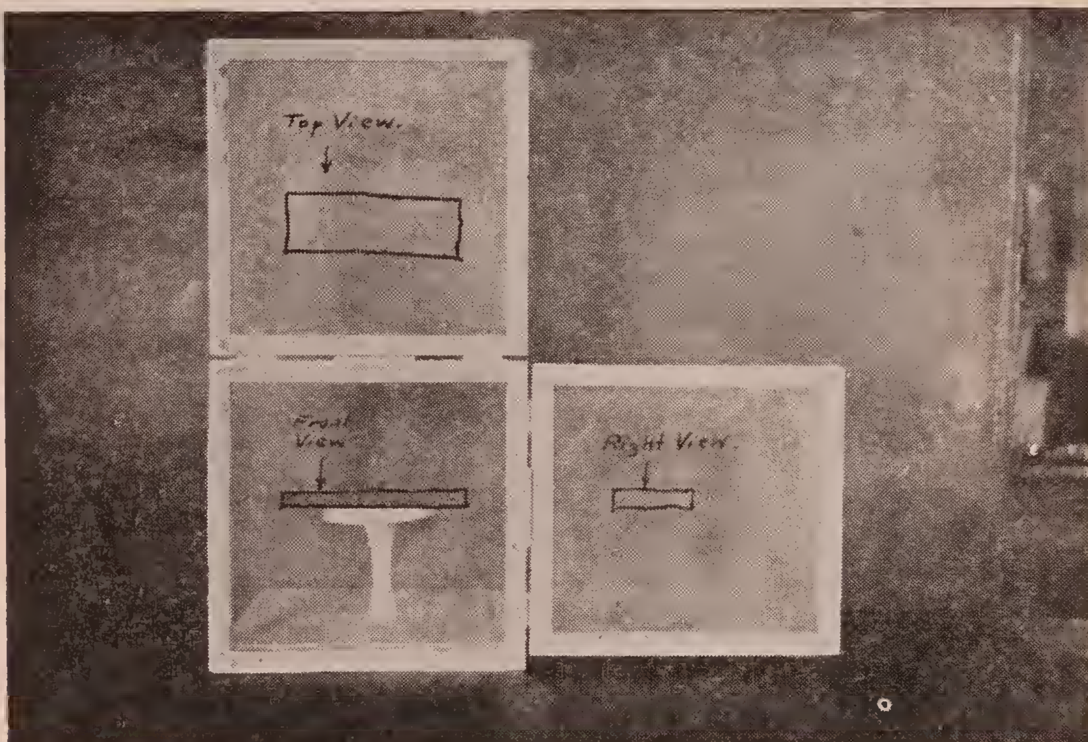


Fig. 4. The projection box with the three views in the same plane.

ject are not obtained by these three projections, so that other planes called *auxiliary planes* are used in order to determine these true sizes and shapes. (See Chapter 42.) The auxiliary plane must be parallel to the surface, the true shape of which, is desired.

Added to this assumption of planes, projections, revolutions and intersections are many conventional methods which have been evolved through many hundreds of years in the history of drafting. Most of these conventions are so well established that their violation would be classed as ignorance or presumption. Some of the conventions are simply the result of practice. Just as in polite society, to eat peas with a knife is a serious breach of etiquette, so to

violate the conventions of mechanical drawing is sim'larly an inexcusable practice.

Fig. 5. A photographic reproduction of a wall hanger.

Some different forms of graphic representation of objects are as follows:

Photographic:—Using a camera, and taking a picture of the object. (See Figure 5.)

Mechanical Drawing:—Two or more views of the object with or without dimensions, often shaded or decorated. (See Figure 6.)

Working drawing:—Dimensioned and detailed mechanical drawings made so that the object drawn may be made from the drawing.

Isometric, cabinet projections, etc:—Easy methods of near true pictorial representation. (See Figures 134, 136.)

Perspective drawings:—Exact line drawing reproductions of pictorial representations (See Figure 130 top.)

The method of making mechanical drawings from projections or planes given above, provides for only three

views. Very frequently views from all four sides of the object are required. For example in house plans, four elevations or views, one of each side are required. The roof plan is made but no bottom view is drawn; rather a floor plan looking immediately down on the floor plane of the house is made. Thus it is seen that the student must learn all of the conventions of mechanical drawing and observe them very closely.

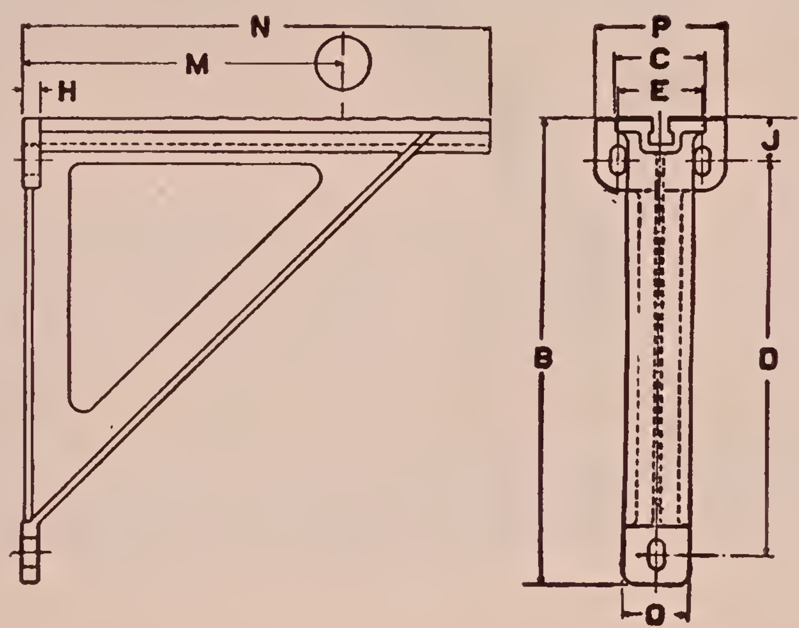


Fig. 6. A mechanical drawing (not a working drawing) of a wall hanger.

CHAPTER II.

PENCILS

Special pencils are made for use in mechanical drawing. These pencils are graded by using the capital letter H, which indicates the degree of hardness of the pencil. Thus,

Fig. 7. The 4 H pencil used for drawing lines.

1 H pencils are only fairly hard, while 5 H or 6 H pencils are very hard. These pencils are made in grades from 1 H to 9 H.

Fig. 8. Another HHHH or 4 H pencil.

Use a 4 H pencil for making all lines of the drawing. A hard pencil makes more accurate lines when properly sharpened than does a soft pencil. It is also true that lines drawn with a hard pencil will not rub off or spread and smear over the sheet as would happen with lines drawn with a soft pencil. The hard pencil will indent the paper; do not bear down on it. Draw lines very lightly from left to right and from bottom toward top.

The 4 H or line-drawing pencil should be sharpened

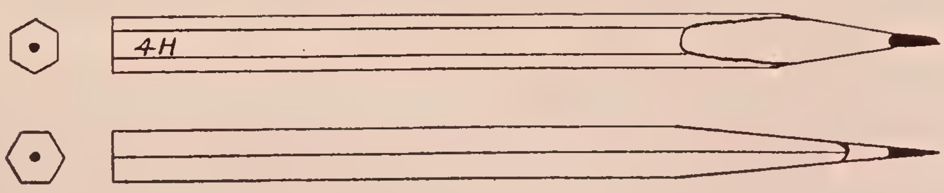


Fig. 9. Shape to which the 4 H pencil should be sharpened.

wedge shaped and the point should be shaped like a knife blade. (See Figure 9.) There are two good reasons for this method of sharpening. In the first place, a knife point is the ideal shape for accurate line drawing. It stays sharp longer than a round point, and its use should result in more accurate work. Secondly, two pencils are needed; the 4 H pencil for line drawing, and the 2 H for lettering. When both of these pencils are of the same color, it would be difficult to distinguish between them if they were both sharpened to a round point. By having the 4 H pencil sharpened flatwise, it is easy to recognize it.

Use a 2 H pencil for making all letters and figures on the drawing. The 2 H pencil is softer and its use in making letters is always recommended. This pencil is sharpened to a long round point. (See Figure 10.) Use a sharp pocket knife for cutting away the wood, exposing about 3/8″

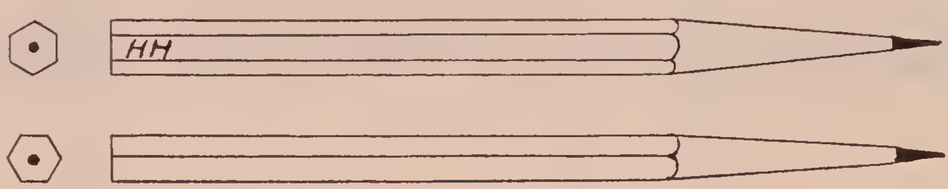


Fig. 10. The shape to which the 2 H pencil should be sharpened.

of lead. Grind this to a round point on a sandpaper pad. (See Figure 11.) Do not attempt to cut the lead with the knife. It would be best in an elementary class for the instructor to shorpen all pencils the first time.

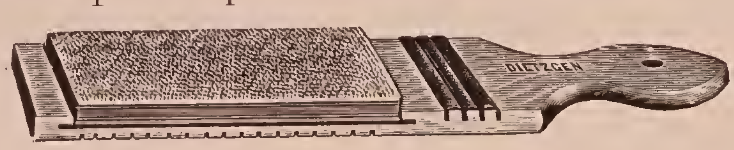


Fig. 11. A sandpaper pad used for pointing drawing pencils.

Other types of pencils are numbered in different ways. The writing pencils which we use in ordinary work are numbered No. 1, No. 2, No. 3, and No. 4. (See Figure 12.) This illustration shows a No. 2 which is the grade we commonly use. No. 1 is the softest, and Nos. 2, 3 and 4 are harder. For

sketching work in art classes a very soft and a very black pencil is desired. For that work a pencil with a large, round,

Fig. 12. The writing pencil commonly used is a No. 2 grade.

soft lead is made. (See Figure 13.) These pencils are graded 6 B to 1 B, H B and F. The more the number of "B's" the softer and blacker the pencils are.

Fig. 13. A sketching or black pencil.

All drawing or sketching pencils must be kept sharp. No great degree of accuracy can be maintained if the pencil points are blunt. Keep the sandpaper pad at hand and whet the pencil points frequently.

CHAPTER III

Lettering Practice

The first work of any new class should be lettering practice. The first period that the class reports should be spent in practice lettering, following the rules given below.

Lettering should be done with the aid of four horizontal guide lines. In this book, the four guide lines will be 1/16″ apart, making the capital letters 3/16″ high and the small letters 1/8″ high.

Letters may be either vertical or sloping, but in either case, vertical or sloping guide lines should be drawn. At the left in Figure 14 are shown four guide lines with vertical guide lines for aiding in keeping letters vertical. At the right of this figure are seen four horizontal guide lines

Fig. 14. Guide lines for vertical or sloping letters.

with slope guide lines. Letters when sloped are made at 15° to 30° to the right of the vertical. These are made 15° to vertical. This slope has been selected for use in this text, and these lines are drawn by setting the 30° angle of the 30°-60° triangle on the tee square and then setting a 45° triangle on this. These two angles, 30° and 45°, make a 75° angle which is 15° less than the right angle.

The lettering used in this text is unknown as the *Reinhardt* simplified alphabet. The word alphabet is derived from the first two letters of the Greek alphabet, Alpha and Beta. In English, we call the alphabet, our a. b. c's. We use three general types of alphabets,—*upper case, lower case,* and *script*. The names, "upper case" and "lower case"

are derived from the type fonts or complete sets of type in the printer's "case." The printer's type is carried in a flat series of boxes, a complete alphabet in each. For setting type the printer has the lower case box nearest to him,

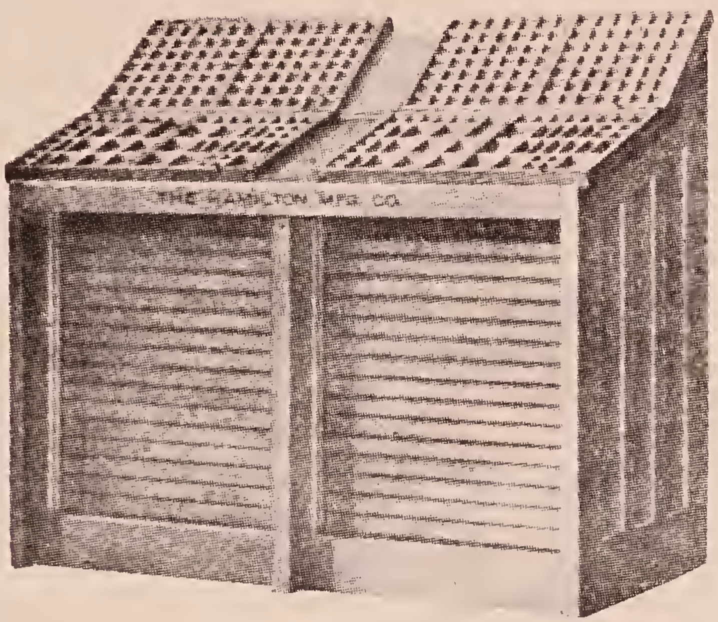


Fig. 15. The printer's type storage case showing **upper** and **lower** case type storage space.

while the upper case, or capital letter box used more infrequently, is further away and over the small letter box. Thus, the terms "upper case" and "lower case" are derived. (See Figure 15) These letters are also called "capitals" and "small letters" or "magiscules" and "miniscules." The third type of letters is called *script* from the Latin word meaning *written.* This is the name given to the written characters representing the alphabet. In printed letters we have only the capital and small letters. Figures do not have upper case and lower case or capitals and small types. The size or height of figures varies with the height of upper case or lower case used.

The Reinhardt upper case alphabet may be divided into three groups. The first and simplest group is based on straight lines. The second group is made up of full or part

curves. The third group combines these two types. See Figure 16.

ILTFEHKVWZXYNMA 147

OQCGS& 09638

PBRDJU 25

Fig. 16. The three groups of upper case letters.

In making letters on the practice sheet, note carefully the above analysis as shown by the grouping and by the dotted lines, and use the alphabet shown in Plate I as a guide. Upper case letters should be sketched. Note that all letters are the same width except the I, M and W. The M is wider than the ordinary letters and the W is still wider.

The lower case alphabet is likewise divided into groups on the same principle. The letters of the straight line group are formed as those in the top line, Figure 17. The round letters are based on an ellipse, the axis of which extends at

ltikvwxz

ø o c e s

o oı a o dbpgq

flohj ıonmıor uy

Fig. 17. The four groups of lower case letters.

an angle of 45° to the vertical. (See Figure 17). On this basis the O letters in Fig. 17, are formed. By adding lines to the second group letters the third group is formed. By combining a part of the curve and straight line, the letters in the fourth group, result.

A closer study of the lower case alphabet shows certain relations of letters and parts of letters.

1. The u is the n bottom side up.
2. The p is the d bottom side up.
3. The m is a double n but not quite twice as wide.
4. The w is a double v but not quite twice as wide.
5. The y is almost the same as an inverted h.
6. The i and the j have dots over the letters.
7. The g and the q are identical except for the direction of the tail.
8. The r is the same as the u with a part of the right upright erased.
9. The f and the j stems are identical when one of them is inverted.

Use the copy given in Plate I for making the lower case practice letters. Spend one or two hours per week practicing lettering. If drawing is studied in the 7th Grade, Upper Case letters should be used throughout this grade.

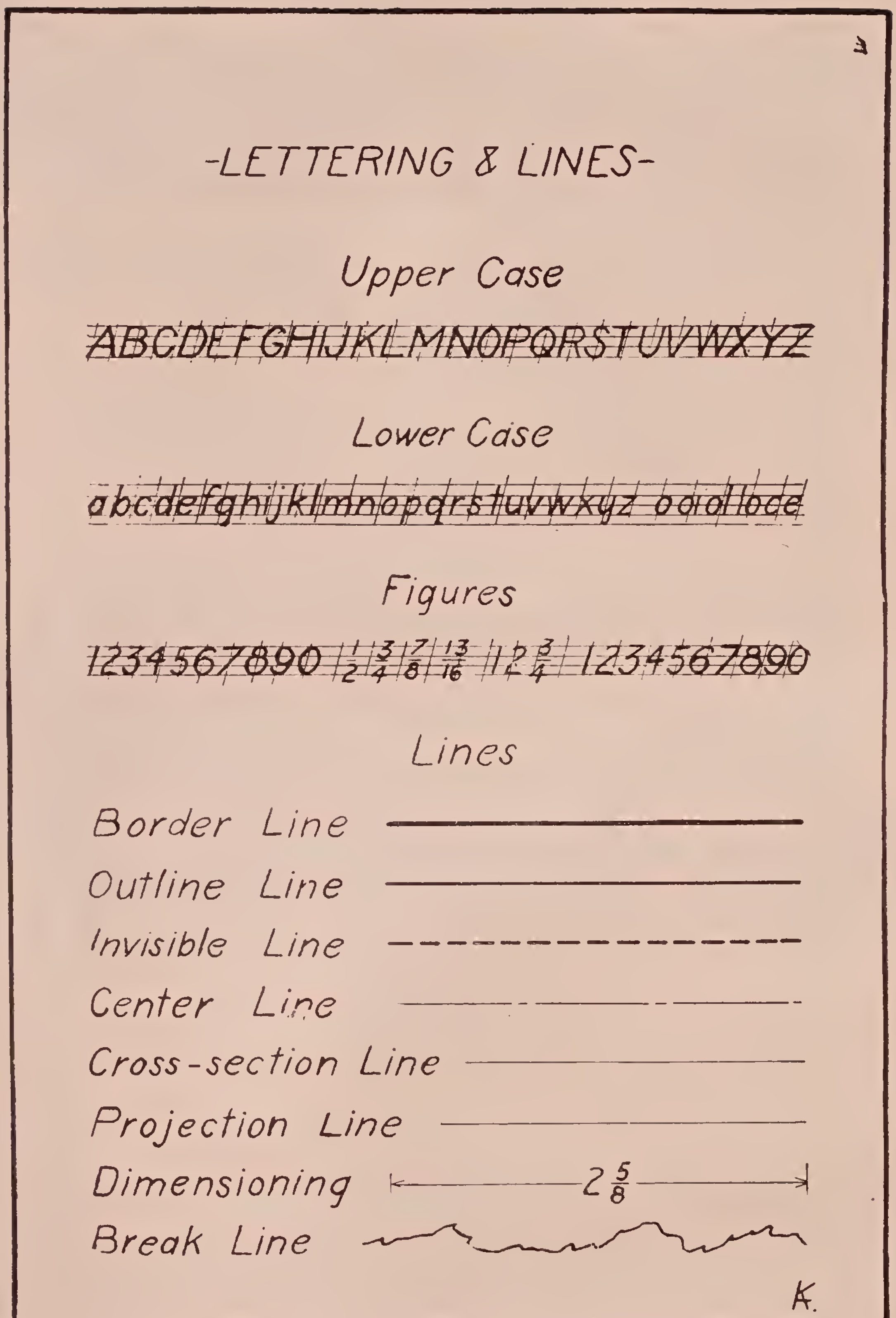


Plate I. Upper and lower case letters and an alphabet of lines. (Drawing made by L. K. Anderson.)

CHAPTER IV

Drawing Paper. Erasing Pencil Lines

There are many kinds of drawing paper; the colors used chiefly are pure white and cream. For elementary work the cream colored paper is to be preferred, because it shows erasures and dirt to a lesser degree. There is some variation in the whiteness of the white paper and in the gloss of the surface of white papers.

Drawing paper may be obtained in rolls and in sheets. For convenience in a school course, the paper should be obtained in sheets cut to correct size. Paper is made up in standard sheet sizes in thicknesses varying with the size of the sheet. The smallest sheets are the thinnest. Standard drawing paper comes in these sizes:

Cap,	14x17 inches
Demy,	15x20 inches
Medium,	17x22 inches
Royal,	19x24 inches
Super Royal,	19x27 inches
Imperial,	22x30 inches
Double Elephant	27x40 inches

The paper for the first group of this series of drawings should be ordered 10″x13½″ and may be cut economically from the 27″x40″ size sheet. By getting the paper from this size sheet, a thick and substantial grade of paper is obtained. The second sheet size is 12″x15½″ and when the 19″x27″ sheet is cut in halves we get a suitable size sheet. When paper is mounted it should be perfectly clean. Every possible precaution should be used to keep it in such condition. Drawing paper when sold in sheets is frequently designated in reams or quires.

When lettering a sheet in pencil, use a piece of scrap

paper under the hands to protect sheet. This will frequently save the sheet from becoming soiled during this work.

When drawing pencil lines on the sheet, draw every line with the fear that it may have to be erased. Then, if erasure is necessary, the sheet will not be indented. Do not bear down heavily on the pencil at any time.

Fig. 18. The ruby eraser, suited to line erasing.

When it is necessary to erase pencil lines, use a reliable eraser and erase carefully just where erasing is needed. Sponge erasers are designed for removing dirt and not for erasing lines. Use a Ruby or other good make of eraser and erase lightly so that the surface of the paper is not spoiled. Green erasers sometimes rub off on the paper.

When erasing a long line, erase next to a straight edge similarly to drawing the line. Erasers must be kept clean, so that when erasing is needed, the results are satisfactory. The hands must be clean, but even then, care must be taken not to allow the hands to come in contact with the paper.

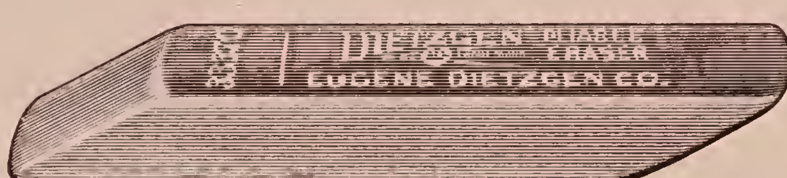


Fig. 18a. Eberhard Faber No. 100 Pink Pearl is a very good soft eraser for line removal.

CHAPTER V

Laying Out the 9x12 Sheet

The sheet used in the first part of this text finishes 9"x12" with a ½" border on all four sides. Each sheet must be exactly the same and should be produced as follows:

Mount the drawing paper on the upper left hand portion of the drawing board with a thumb tack in each of the top corners.

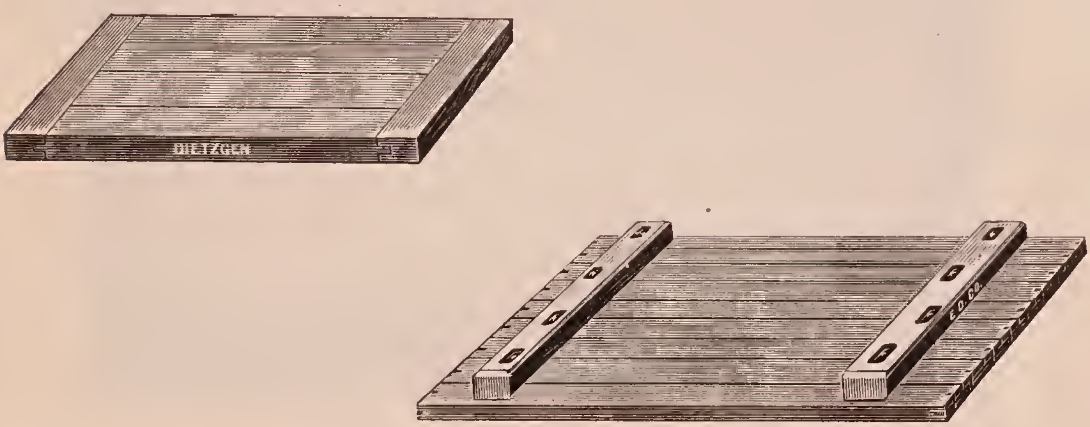


Fig. 19. Two common types of small drawing boards.

Figure 19 shows a drawing board made to allow for shrinkage. The top face of the board should be smooth and clean. This face should be planed and sanded as often as is necessary. The left end must be straight.

When buying drawing paper, do not allow the salesman to roll it. Keep it flat at all times; two tacks will then be sufficient to hold it in place on the board. Carry the spare sheets in a portfolio large enough to insert the paper. Home-made portfolios are easily produced. Building paper and a cheap riveting machine make their production an easy matter. (See Figure 20.)

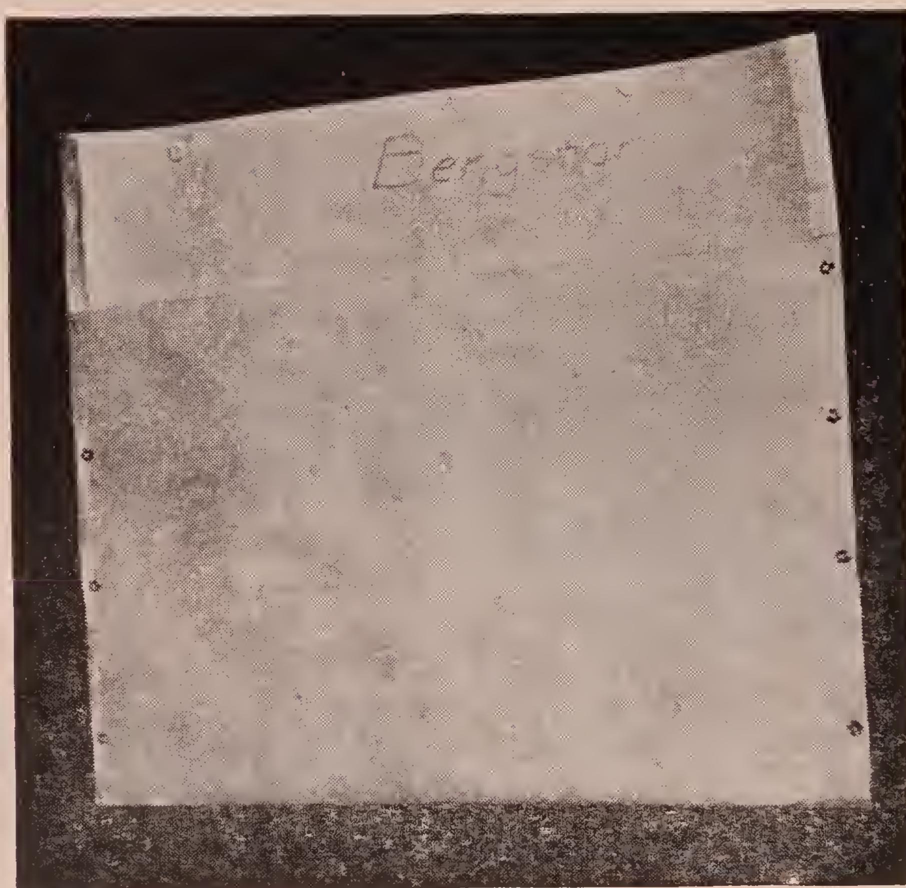


Fig. 20. A home-made portfolio.

Several types of thumb tacks may be secured. The type where they are sold by the dozen and packed in round tin boxes is more suitable for public school use. The tacks should be of the small size and should be pressed into the drawing board with the thumb. Do not drive them in with the tee square. They can be removed by inserting thumb and finger nails under edge and twisting the tack. Or insert

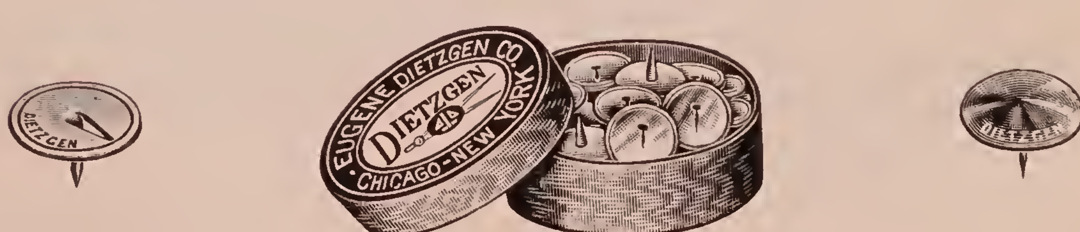


Fig. 21. Thumb tacks and a convenient form of container.

a knife blade under the tack to remove it. A thumb tack puller may be purchased. (See Figure 30).

After the paper is mounted the border lines of the sheet should be measured off. For this we use the Architect's Scale. There are three words we need to understand:

A rule is a device for measuring length. It may be 1′, 2′, or 3′ long. Each inch is usally divided into halves, quarters, eighths, and sixteenths. (See Figure 22)

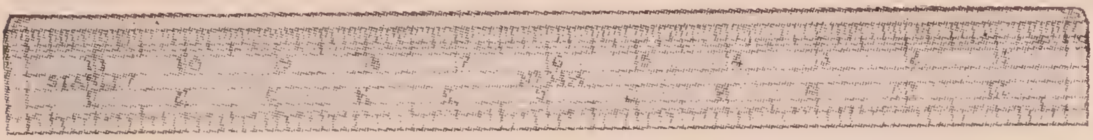


Fig 22. A one-foot school rule.

A ruler is a straight board or device used for drawing straight lines. Usually it has no inch marks on it. (See Figure 23)

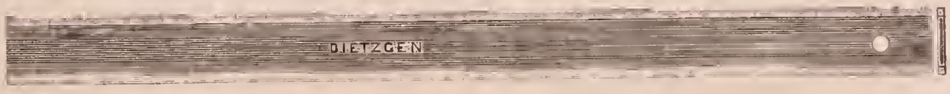


Fig. 23. A ruler or straightedge.

A scale is a device which has a rule on one edge and several "scales" on the other edges. Our Architect's scale has three edges, six faces for calibrations and eleven different scales. One edge has a 12″ rule for measuring inches, halves, quarters, eighths, and sixteenths. (See Figure 24). The other edges have two scales on each, one beginning at either end. The scales found on the Architect's Scale are 3/32″=1′, 3/16″ =1′, ¼″=1′, ⅜″=1′, ½″=1′, ¾″=1′, 1″=1′, 1½″=1′, 3″=1′

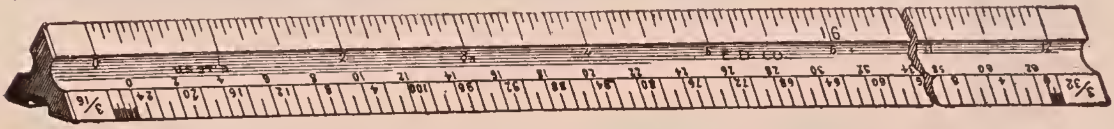


Fig. 24. The Architect's or Mechanical Engineer's scale.

The Civil Engineer's scale, usually called an *Engineer's Scale*, has a 12″ rule on one edge, each inch of which is divid-

ed into tenths. The other five faces have the inch divided into twentieths, thirtieths, fortieths, fiftieths, and sixtieths. (See Figure 25.)

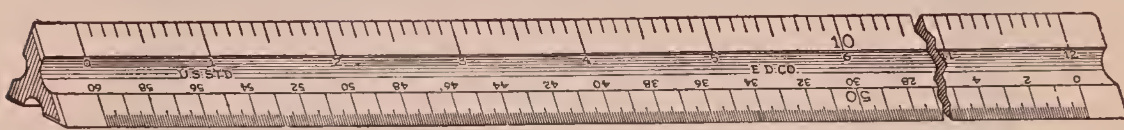


Fig. 25. The Civil Engineer's scale.

When using scale, mark off lengths on top edge and on left edge of scale. This allows hands to rest on scale instead of paper and thus the paper is kept reasonably clean.

When laying off several measurements whose total is less than 12″, *make them without moving scale.* This tends towards greater accuracy. For example, suppose five 2″ spaces are required. If the scale is moved each time a 2″ space is laid out, would the five spaces measure exactly ten inches? The total length might be over or under 10″, while if the five spaces had been laid out without moving the scale, the total would be exactly 10″.

Do not use the scale for a ruler or straightedge. The edges are so thin on the triangular scale that they usually become nicked and marred, and few scales are actually straight. They are not designed to be used as rulers, or to draw lines.

Fig. 26. A wooden tee square with lined blade.

Horizontal lines are drawn on top edge of tee square with 4-H pencil from left to right.

The head of the tee square is always held against the left end of drawing board. These two rules are never v olated. The tee square is never placed in any other position. Lines are never drawn on bottom edge; indeed, some tee squares are made with bottom edge cut at an angle, so that it cannot be used for line draw ng. (Fig. 27.) The head of the tee square is never held on any side of the drawing board except the left edge. The board might not be square.

Fig. 27. A tee square with bottom edge tapered.

Vertical lines are drawn on left edge of triangle from bottom to top. The other edge of the triangle must be in contact with top edge of the square. Because:

1. Light should come from left front.
2. Hand does not drag on paper.
3. Hand drags on triangle and holds it down.
4. Inking may be done this way best.

Either triangle may be used for this. The triangles usually furnished for a drawing course are as follows:

The 45° *triangle is one which has one* 90° *and two* 45° *angles.*

The 30°-60° *triangle is one which has one each* 90°, 30° *and* 60° *angle.* The sum of three angles in any triangle is 180°. These triangles may be purchased in various sizes, those from 4″ to 12″ being easily obtained. The triangle must be held firmly against the tee square for careful work. In the better grades of triangles a place is cut in the inside

edges of triangle to aid in lifting the triangle off the sheet. (See Figure 28)

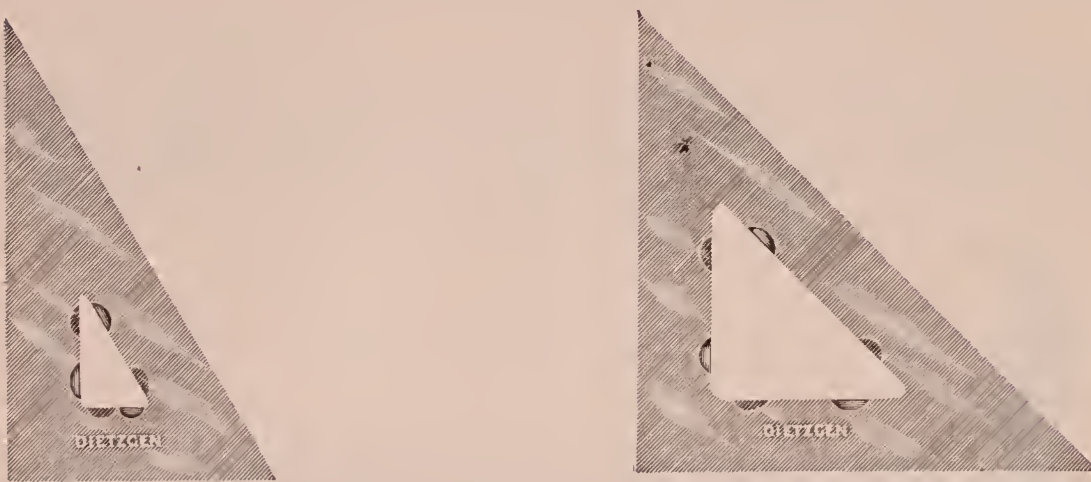


Fig. 28. The 30°-60° and 45° triangles.

Do not slide triangle from one part of paper to another. Lift it up and carry it to the other place. This aids in keeping the sheet clean. Before starting to draw, the triangles, tee square, and drawing board should be dusted clean with a dust cloth or a handkerchief. But this is not sufficient. If the triangles are dragged or slid across the sheet, dirt is sure to be rubbed off on the sheet.

Follow this order in laying out the standard 9″x12″ *sheet.* In doing this play a game of solitaire; wager with yourself that you will not at any time permit any portion of your hand or fingers to come in contact with the paper. When you are through, count the number of times you have touched the paper.

1. Mount the 10x13½″ paper as indicated in Fig. 29. Use 2 thumb tacks very close to the top corners.

2. Measure from left to right in middle of sheet ¼″, ½″, 12″, and ½″. This will leave approximately ¼″ waste on right.

3. With nought of Scale at bottom and the 10″ mark at the top, mark the ½″ point and the 9½″ point. This lays out the 9″ sheet and leaves ½″ borders at top and bottom. If the

sheet is not exactly 10″, split the difference at top and at bottom.

4. Draw the vertical lines first. Since the usual triangle is not long enough to draw all of the vertical line, draw the top half of all lines first. The outside lines are trim lines and extend to the edge of the sheet. The inside lines are border lines and extend to within ½″ of the edge. Do not draw them all the way to the edge, but stop them within ½″ of the edge. Draw the bottom half of these lines in like manner.

5. Now draw with the tee square, the top and bottom border lines between the inside lines drawn in (4).

Fig. 29. Drawing the pencil lines laying out the 9x12 sheet.

Now locate lines for standard lettering on the inside of the 9x12 space as follows:

1. Set scale with nought at bottom and nine at top margin. Mark off inside of each border line these distances, 1/8″ 1/16″, 1/16,″ and 1/16″. With nought at left margin and twelve on right margin, mark off ½″ from each margin.

2. Draw the stop lines (2) in Plate II.

3. Draw the lettering guide lines about 2″ long at top and entirely across bottom. (See Plate II)

4. Lay off the middle 4″ of bottom for name of high school.

5. Draw 15° slope guide lines at each place where lettering is to be placed.

Put name of high school in middle 4″ of bottom guide lines, in upper case letters.

Put date in lower left corner in lower case letters. Do not abbreviate.

Put your name in lower right hand corner in lower case letters.

Put Drawing No. 1 *in upper right hand corner in lower case letters.*

After drawing has been completed on the 9x12 sheet, put the name of the drawing in the middle of top space and in the center of the sheet from left to right.

Lay out four or five sheets completely and neatly lettered so that they will be ready for the drawings to be put on them later. Number them: 1, 2, 3, 4 and 5.

Fig. 30. Two styles of thumb tack lifters.

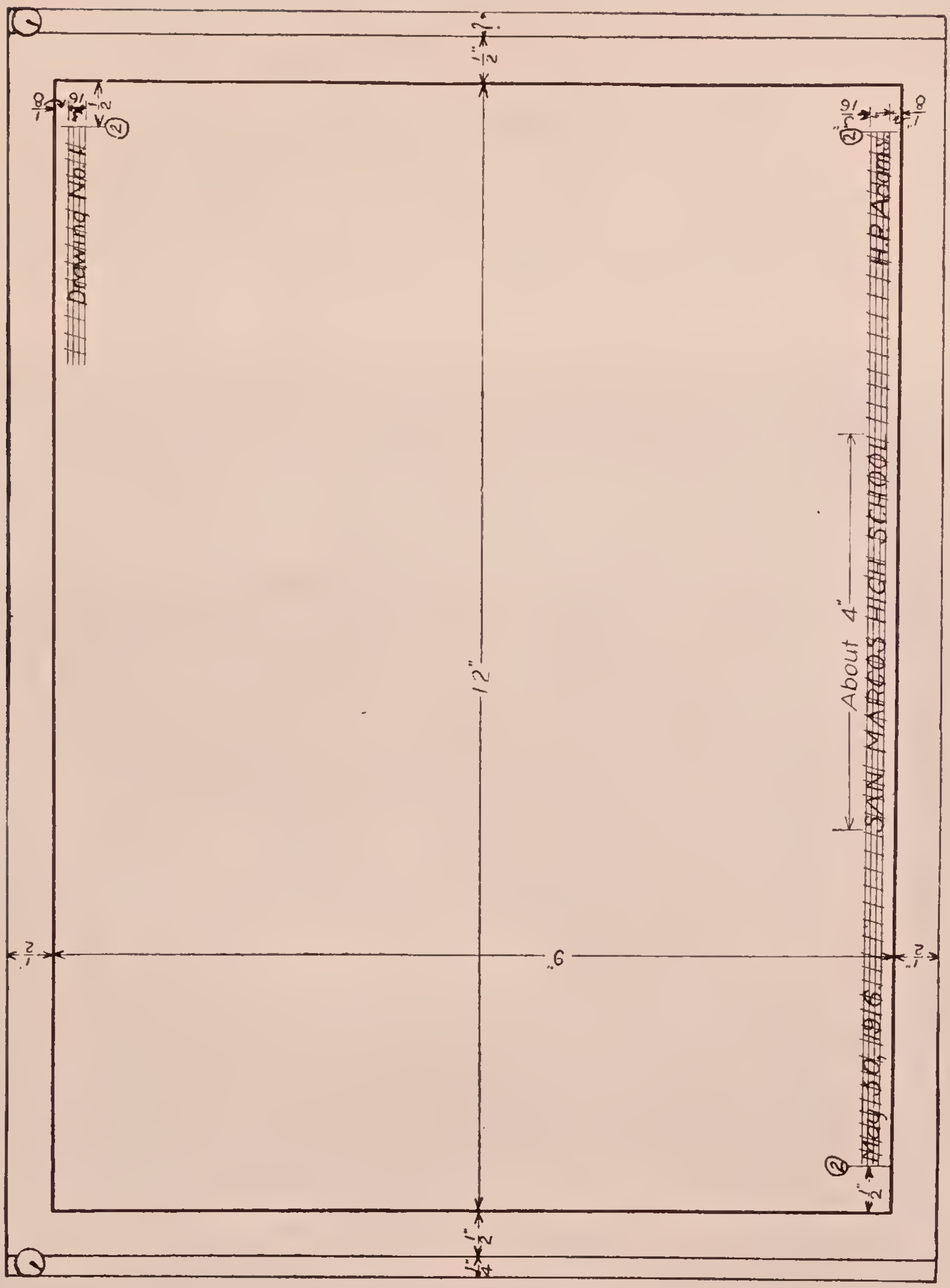


Plate II. Details of the 9x12 sheet.

CHAPTER VI

Making Preliminary Sketches Before Making Working Drawings

In Chapter I the general principles of mechanical drawing were presented. Before making a working drawing of an object it is necessary to make a sketch of the views required, put dimensions on this sketch and plan the layout of these views on the sheet. Otherwise, many mistakes would be made, and in many cases the sheet would be so badly laid out that it would need remaking. Or if a person is drawing a machine part, he would get the sheet very badly soiled if he worked directly from the model.

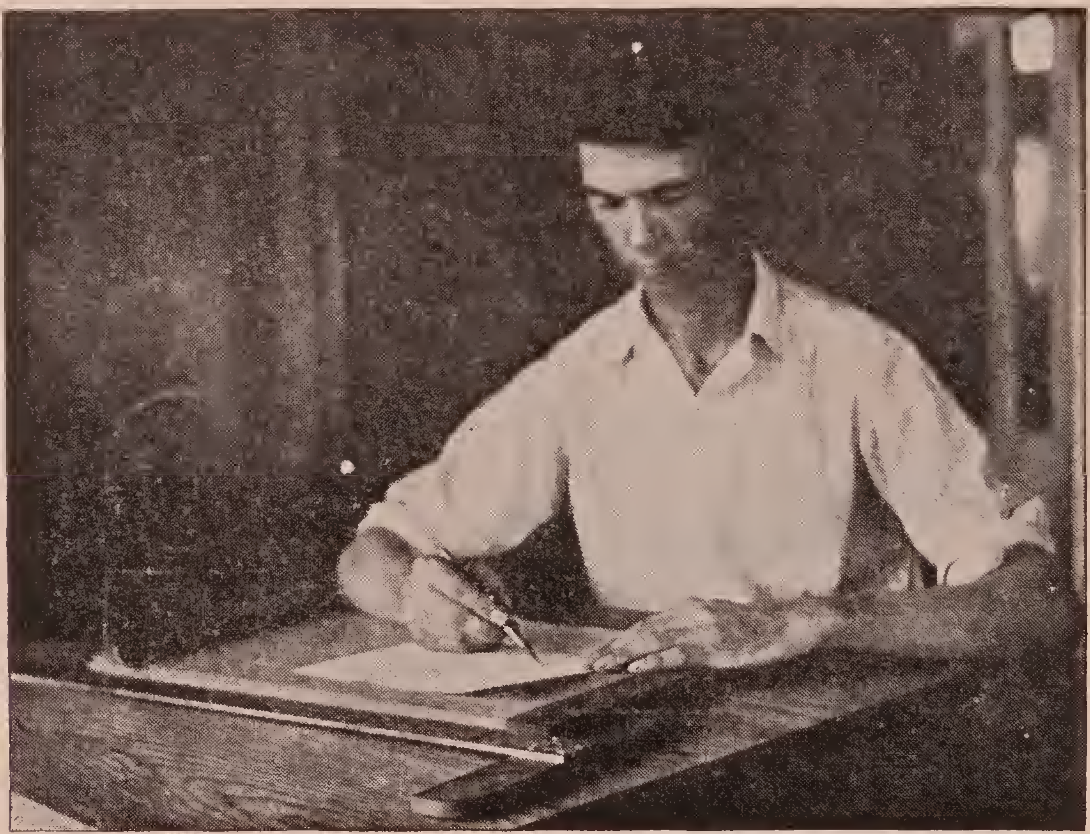


Fig. 31. Position of hand and pencil when sketching a horizontal line.

It is recommended that each student be required to make a sketch of the problem assigned and have the instructor check and okeh it before any sheet in this text is started. A few basic rules of sketching are given to aid the student in making these preliminary drawings.

When sketching a horizonal line, turn the paper slightly and hold the pencil at an angle of about 30° to the surface of the paper and perpendicular to the direction of the line. The elbow becomes the center of the arc of motion and the line is sketched by fragments. (See Figure 31)

Fig. 32. Position of hand and pencil while sketching a vertical line.

When sketching vertical lines, turn the paper slightly to right and sketch the line by a movement of the fingers. The hand is moved downward as is needed. This permits the student to make very accurate lines. (See Figure 32.)

When making sketches, maintain the correct proportion

between length of lines. If the problem of sketching a 2″ square is assigned, the four sides should be equal in length. If the problem of sketching a 1″x3″ rectangle is given, the sides should be three times as long as the ends.

When sketching circles, draw two perpendicular center lines and lay off approximately equal distances from intersection on these lines. This affords a guide for drawing the circle. Start sketching both ways from each of these points. Measure with pencil or piece of paper.

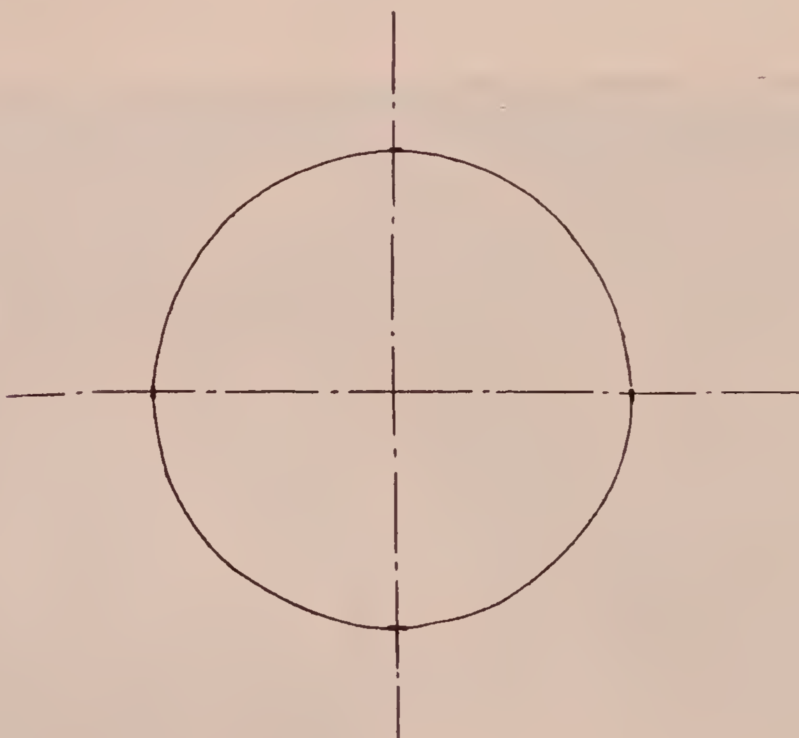


Fig. 33. Method of sketching a circle.

Using a sheet 10x13½″ drawing paper, sketch the following problems:

1. Draw a horizontal line five inches long. After it has been drawn, measure to see how closely you have guessed five inches.
2. Draw a vertical line three inches long.
3. Draw a 1″ square.
4. Draw a 1″x4″ rectangle.

5. Draw an equilateral triangle with sides 3″ long.
6. Draw a circle having a diameter of 3″.
7. Draw a circle having a diameter of 7″.

CHAPTER VII

Making the Drawing

In Chapter I the fundamental basis of mechanical drawing was established. The origin of the three views was explained and their relative position was determined. Another conception of the establishing of the position is now presented. Any object has six directional sides or faces: north, south, east, west, top, and bottom. Or stated in another way, any object has a top, a front, a right side, a left side, a rear or back, and a bottom. Thus, if the six surfaces or faces of a bench are drawn (Figure 34) the four showing the height may be put in line; the left being naturally placed to the left of the front, the right being placed to the right of the front, and the back view either to the right or left of these three views. Views showing lengths are placed even, so that with the front view located, the top is naturally placed over the front with the bottom placed below.

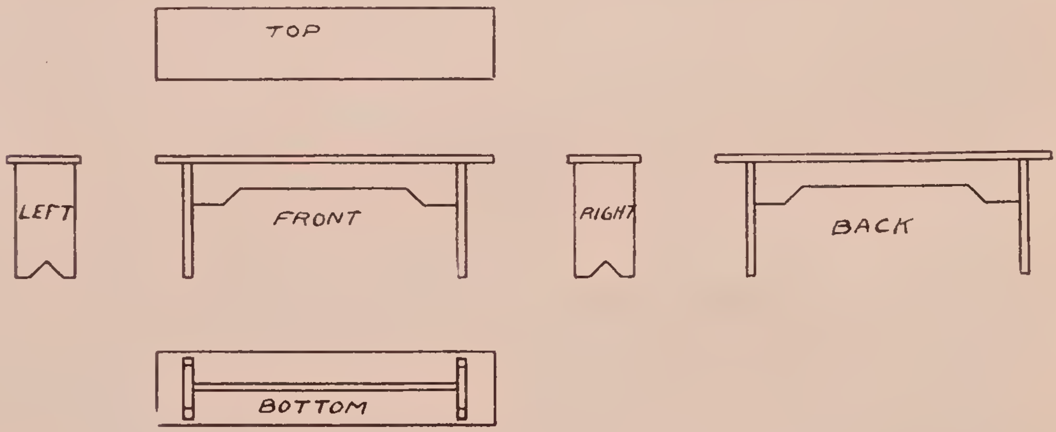


Fig. 34. Six views of a bench.

It is readily seen that the top and bottom views are almost identical, the left and right views are the same, and the front and back are duplicates. This gives rise to the rule: *A*

mechanical drawing generally consists of three views: the top view, the front view, and the right view. The top shows more than the bottom, except in house plans (house plans are not really bottom views); hence its selection instead of the bottom. The right and left views are usually almost the same, so there is little choice between them, and the front shows more than the back, so it is chosen.

The top view is always placed over the front view, and the right view is always placed to the right of the front. These positions, besides having been established in Chapter I, are the natural positions. Stand in front of a table or a roll top desk. The top is seen over the front; the right is to the right of the front. Figure 34a shows three views of a bench where an attempt has been made to put the right view to the right of the top. Note that this throws this view of the bench on edge, which is unreasonable. Therefore, do not violate the above rule. In solving the sketching assignment below, follow the rules just set forth.

Using a piece of standard pencil drawing paper, theme paper size, sketch the following problems. Sketch each one on separate sheets.

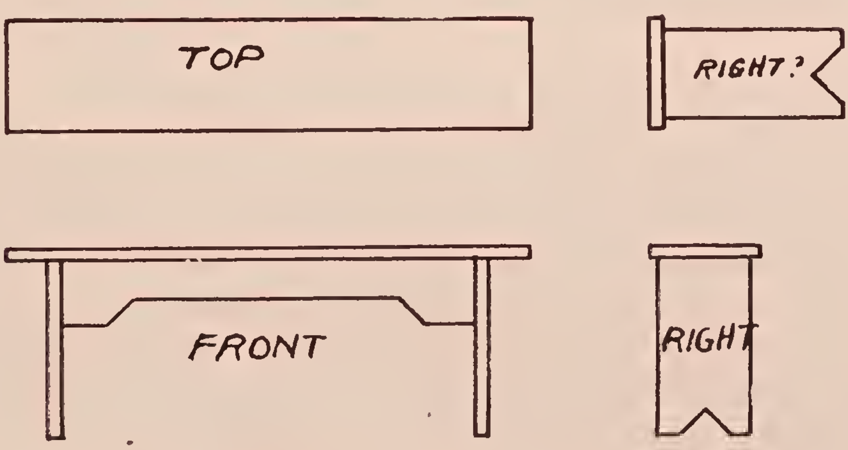


Fig. 34a. Top, front, and right views of a bench.

1. Sketch three views of a rectangular solid, 2¼"x4¼"x 7". The largest surface is the front view. (See Figure 35)

2. Sketch three views of a rectangular solid, 2½"x3½"x 7"; the largest surface is to be the top view.

3. Sketch three views of a solid, 3"x3"x5", if the solid stands on end.

4. Sketch three views of the same solid with one end as the front view.

5. Sketch three views of a 3½" cube.

6. Sketch three views of each problem given in Plate III.

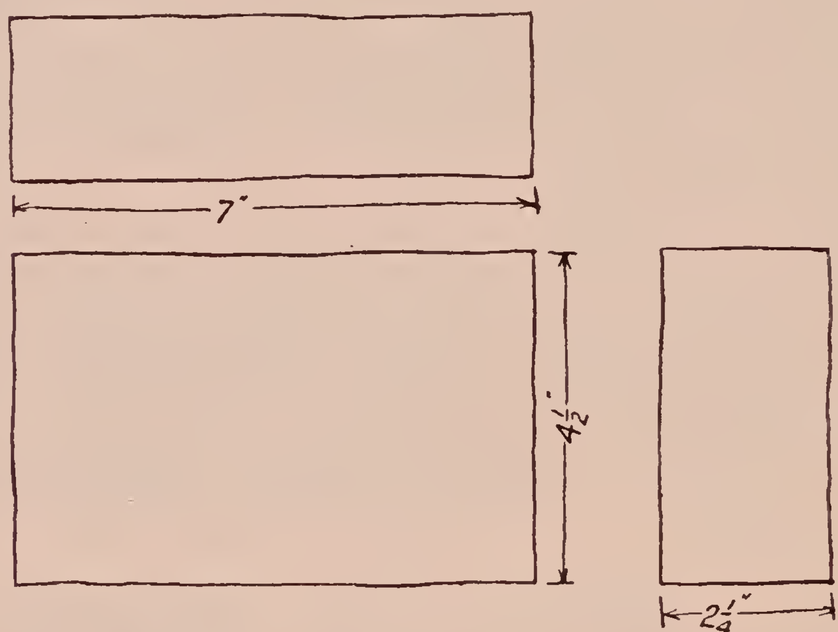


Fig. 35. Three views of a block, 2¼"x4½"x7".

In planning the problem (Figure 35) to fit the 9x12 sheet, we find that there is 6¾ inches of drawing vertically for a 9" sheet. This leaves 2¼" for three spaces or ¾" for each space. When we figure lenghtwise we find 9¼" of drawing with 12" of space or 2¾" for three spaces. Put ¾" in the middle and 1" for each outside space. (See Figure 35a). With this method of planning work we can deduce some rules for procedure:

Spaces at top and bottom should be equal but each should be slightly larger than inside space.

Space between top and front and front and right should be equal if it is convenient.

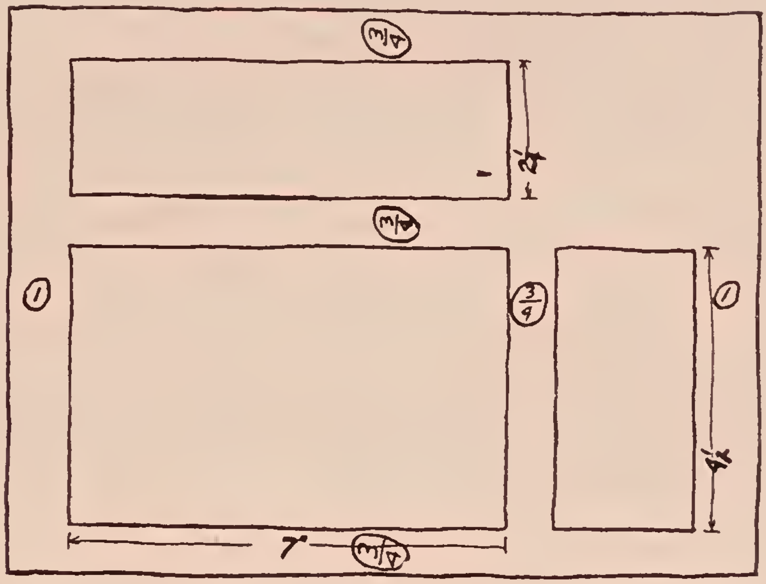


Fig. 35a. Method of indicating spacing for the drawing.

Spaces at right and left of drawings should be equal and should be slightly larger than middle space.

Put amount of space in a circle on sketch.

When drawing this problem on sheet numbered one, follow this detailed instruction.

1. With nought at bottom and 9 at top margin, mark off 3/4″, then 4½″, then 3/4″, then 2¼″ and ¾″ should remain.

2. With nought at left and 12 at right margin, mark off 1″, then 7″, then ¾″, then 2¼″ and 1″ should remain.

3. With tee square, begin at top of sheet and draw all horizontal lines, drawing approximately as much of each line as will be needed.

4. With triangle on tee square, begin at left of sheet and draw all vertical lines between lines drawn in (3).

All outside lines of views should be located, the view thus being "blocked out," by drawing light pencil lines.

After views have been blocked out, heavier pencil lines may be drawn over lines representing the views.

Drawing No. 1—Follow instructions given above and make three views of the 2¼"x4½"x7" and block on sheet 1. Put name of sheet in center of the upper ¾" space in Upper Case letters. Name, "Rectangular Block."

Drawing No. 2.—Make three views of any problem illustrated on Plate III. Name the sheet as indicated on this plate.

Drawing No. 3—Draw three views of any problem given in Plate IV.

Notes. Do not dimension any drawing until definitely instructed to do so.

The name of any sheet should be the same as that given on the Plate from which it is taken.

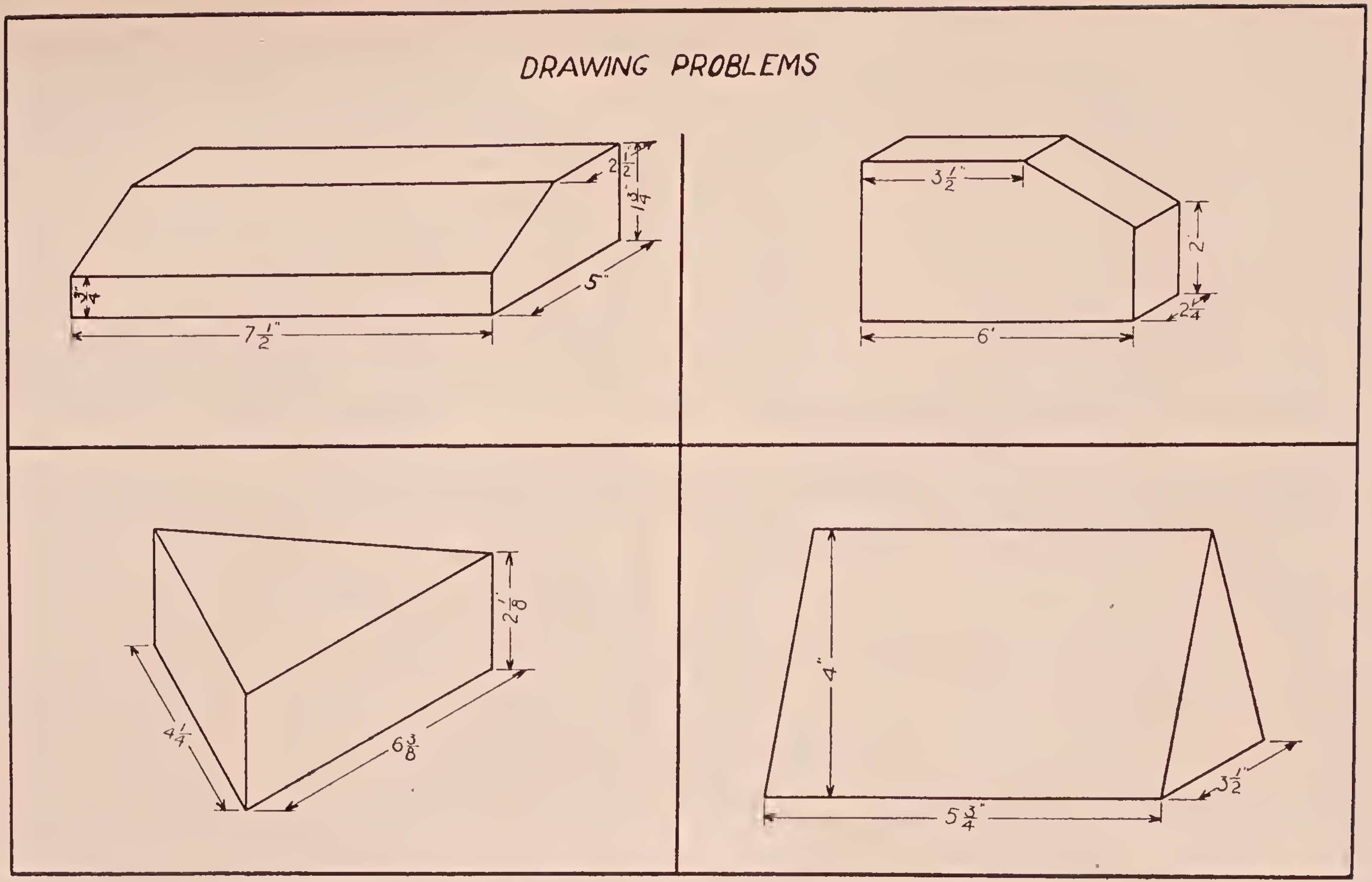


Plate III. Drawing problems involving visible straight lines.

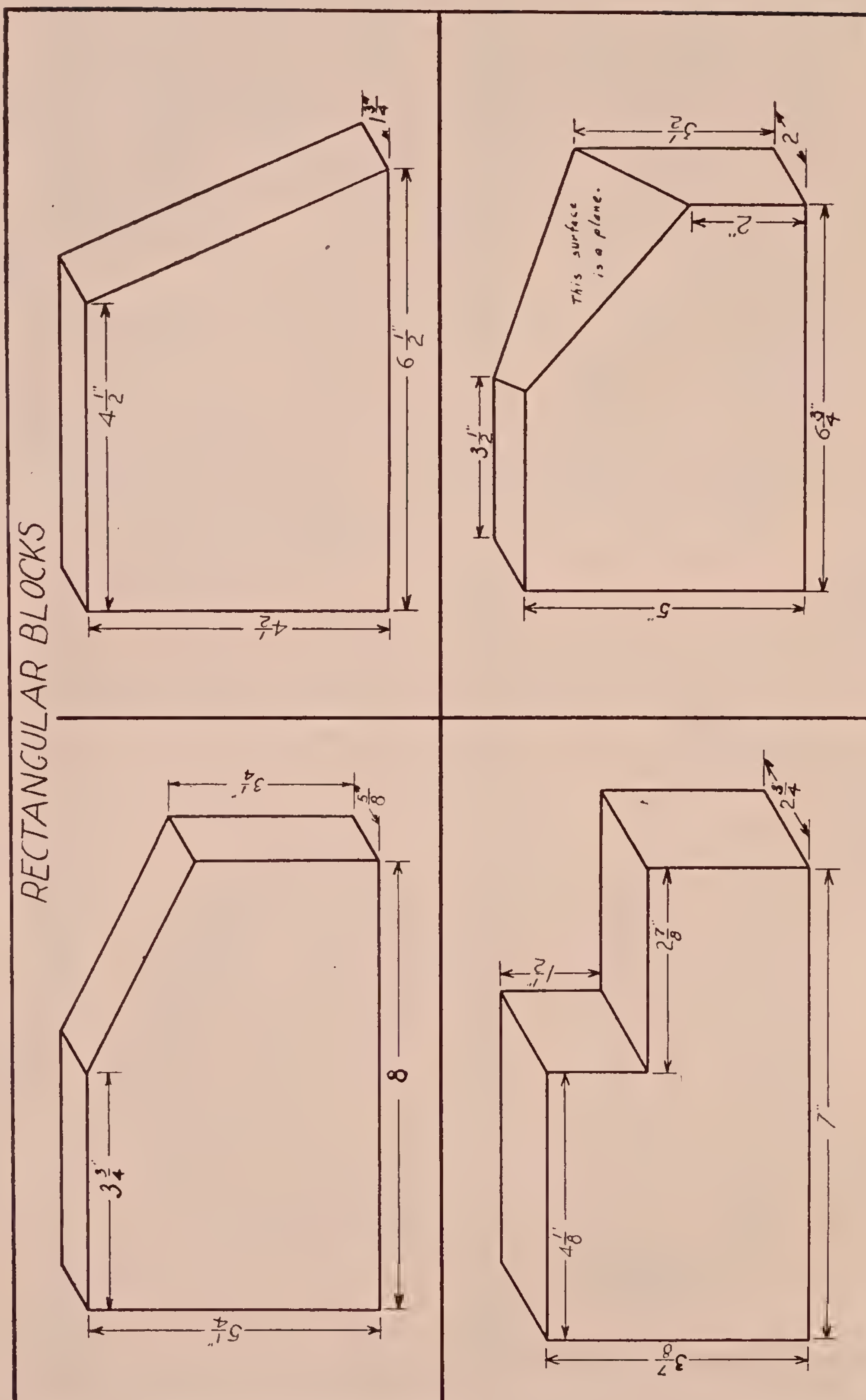


Plate IV. Drawing problems of rectangular blocks.

CHAPTER VIII

Invisible Lines

When all lines are visible in the three views the lines representing them are drawn solid. However, many objects are drawn that have invisible details. For instance, the rectangular solid in the sketch below has a rectangular hole through it. (See Figure 36) The top view shows the hole, but when the front and right views are drawn, the hole cannot be seen.

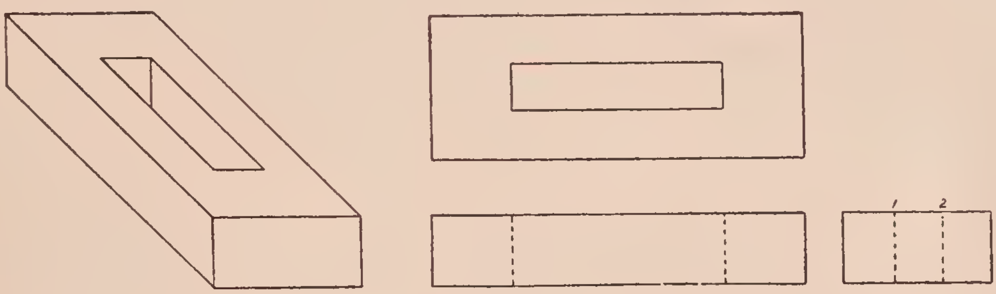


Fig. 36. A block with a hole in it. Representing invisible lines.

All lines that cannot be seen and are not covered by a line that can be seen are represented by dotted lines.

Thus the front view has two dotted lines showing the length of the hole and the end view has two lines showing the width of the hole. *The last dot should touch the line at which the dotted line ends.* Especially is this true when the drawing is inked. Any other procedure will result in poor work. (Compare 1 and 2 in Fig 36). Each dot should be about ⅛″ long and the space should be 1/16″.

The invisible line is an outline line, but is made lighter than the outline line in most alphabets of lines. For the beginner the invisible line may be inked the same weight as outline lines. See Plate I. The advanced student should ink it a little lighter. See Plate XVI.

Drawing No. 4. Draw three views of any problem given on Plate V.

Drawing No. 5. Draw three views of any problem given on Plate VI.

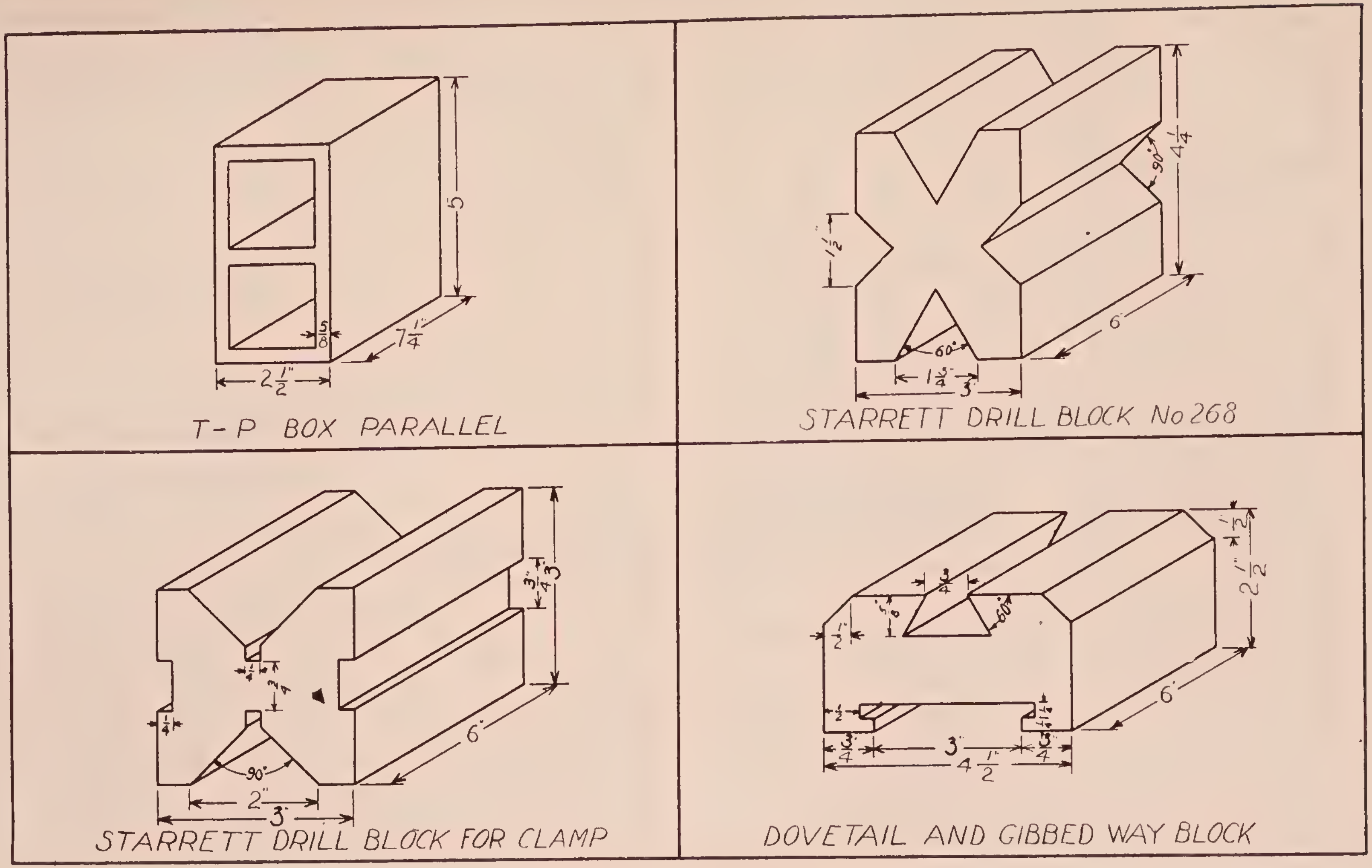


Plate V. Problems containing invisible lines.

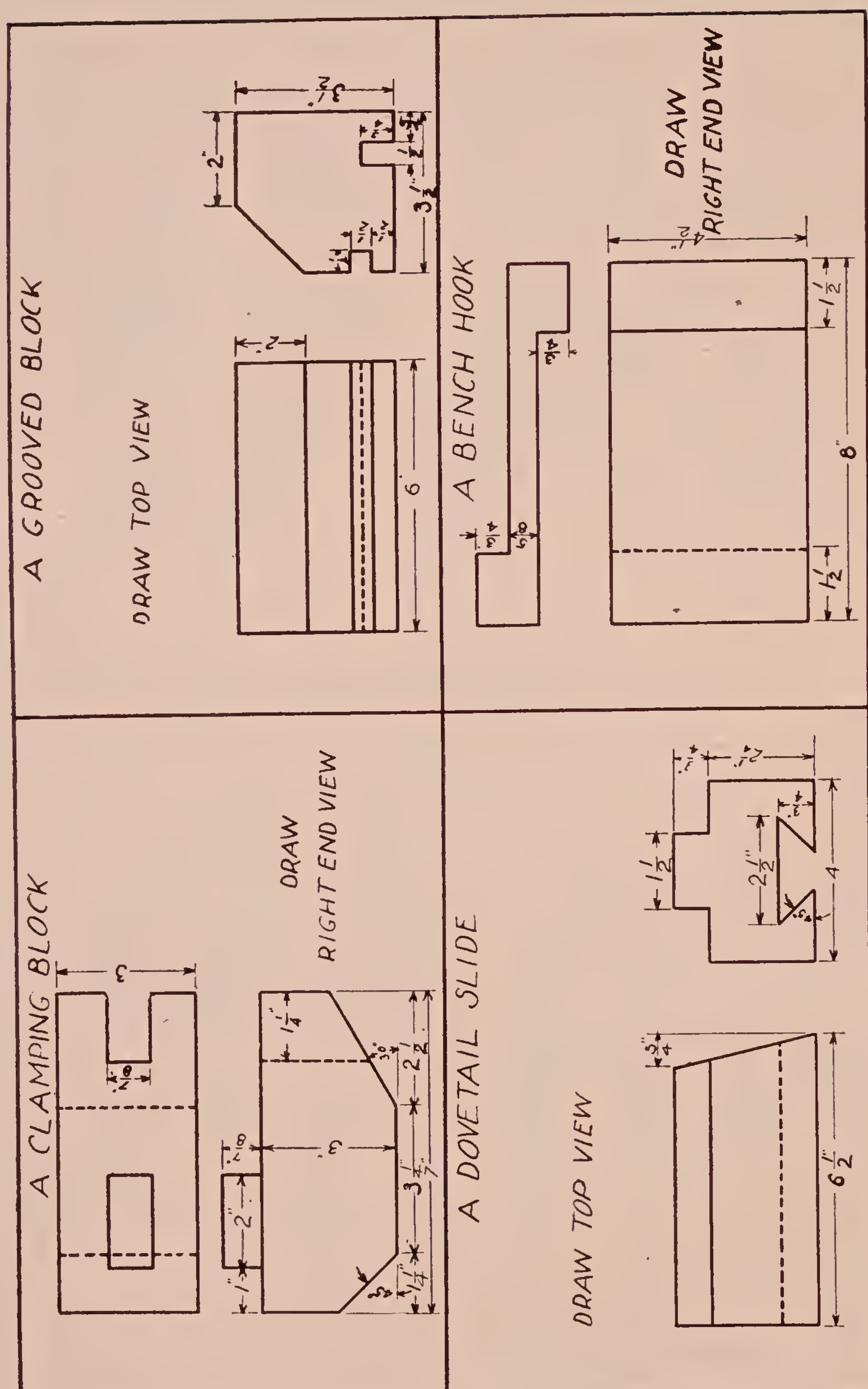


Plate VI. Problems containing invisible lines.

CHAPTER IX

Representing Chamfers

A 45° chamfer may be drawn in all three views from only one measurement. The chamfer is used in many projects in woodworking and also in many machine parts. It is used for two purposes: first, to relieve and protect the sharp arris from indentations and abrasions; second, as an easily produced decorative effect. Since the new planes forming the chamfer make more intersections with the face planes of the solid, more lines will be represented in each view.

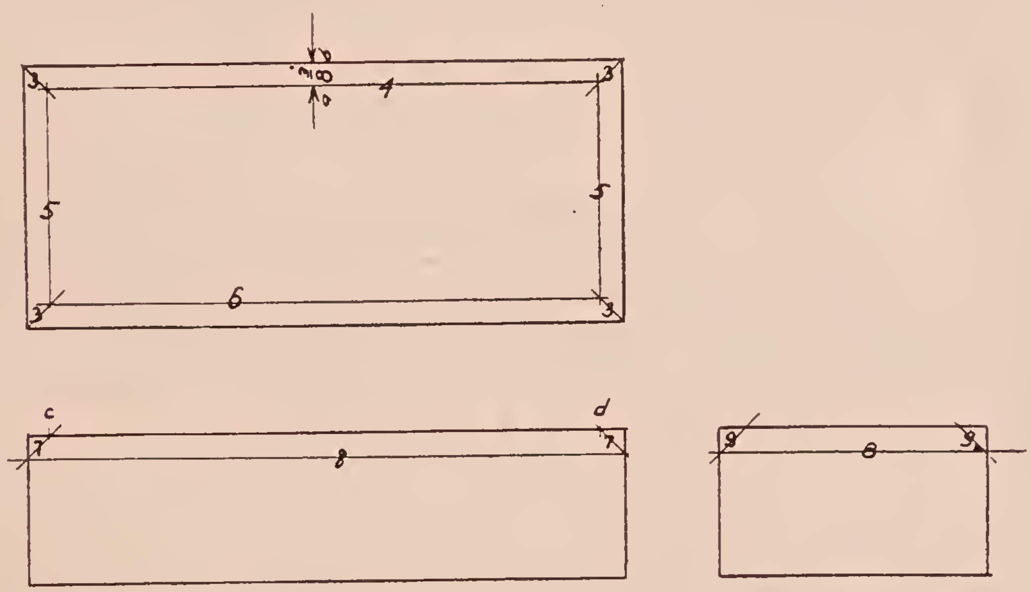


Fig. 37. Drawing a chamfer in three views from one measurement.

Figure 37 shows a chamfer represented completely in three views of a block. To draw all of the lines representing the chamfer from one measurement, proceed as follows: first, lay out and draw blocking-out lines of the three views; second, make desired measurement, 3/8″, at any point, as at a-b; third, draw all 45° lines in top view, of approixmately the correct length; fourth, draw a horizontal line through a, intersecting the top two 45° lines; fifth, draw two vertical

lines through intersections formed in fourth and at same time locate points c and d in front view; sixth, draw horizontal line through intersections formed by 3 and 5; seventh, draw two 45° lines from points c and d, locating chamfer in front view; eighth, where lines drawn in 7 intersect sides of front view, draw horizontal line across front view, and without moving tee square, draw line across right view; ninth, draw the two 45° lines in right view to complete chamfer.

While it is not essential that all representation of all chamfers should be completed by drawing the lines from one measurement, it is most desirable that a young draftsman should know that it is possible. Much time can be saved, and greater accuracy will result if as many measurements as possible are projected from one view to the others.

Do not make the same measurement on any two adjacent views if it is possible to make it on one and project to the other.

By adjacent views is meant top and front, front and right, front and left, etc. Thus, it is best to lay off all heights on front or right and project to both views from the one measurement and lay off all lengths on top or front and project from these measurements. Transfer measurements from top to right by using dividers or by re-measuring.

Drawing an oblique chamfer requires two or more measurements.

An oblique chamfer is a flat chamfer cut off at any angle not 45°. Both dimensions are usually given. See Ring Stake, Plate VIII; the two dimensions in this case are 5/16″ and ¾″.

To draw an octagon having a square given: Measure half the length of diagonal back in both directions from each corner; connect these points, using 45° triangle for drawing lines. Fig. 38.

Drawing No. 6. Draw three views, top, front and right, of one of the chamfered blocks shown on Plate VII.

Drawing No. 7. Draw three views, top, front, and right, of any one of the problems shown on Plate VIII.

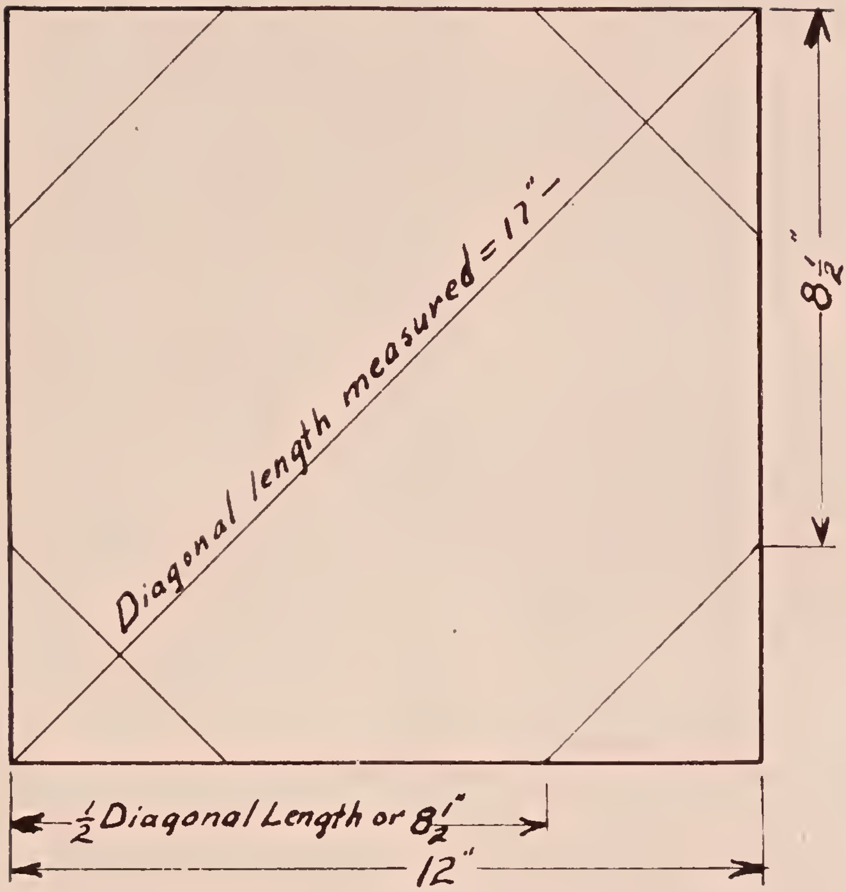


Fig. 38. Laying out an octagon having a square given.

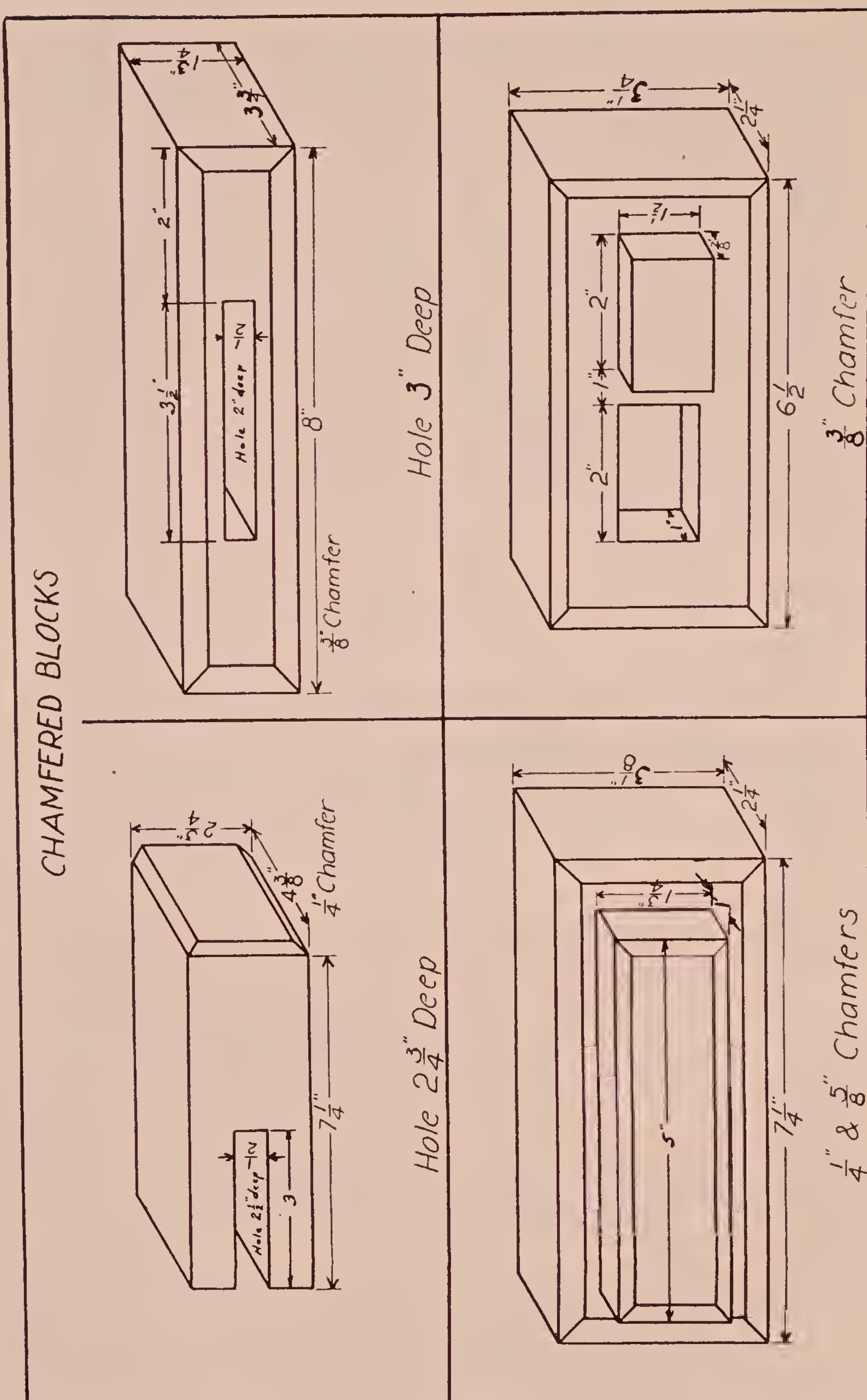


Plate VII. Chamfered blocks.

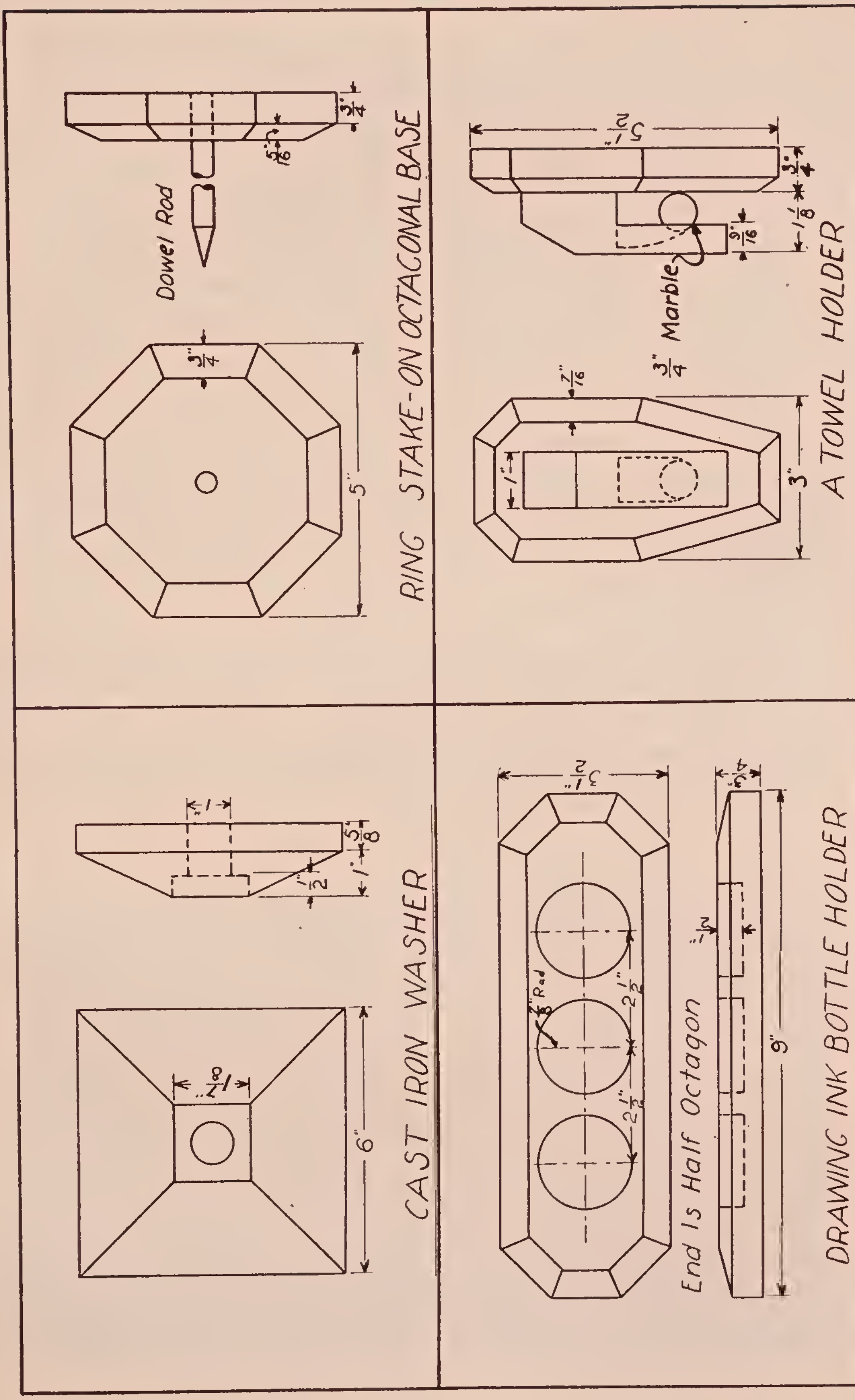


Plate VIII. Problems containing chamfers.

CHAPTER X

Round Holes in or Through a Solid

A round hole in or through a solid is represented by a circle in one view and by invisible or dotted lines in the other views. Round holes are generally made by boring with auger bits or with drill bits, though in sheet or plate metals, they may be punched. For the purpose of centering the bit or drill, the center of the hole must be located first. The center of the circle is a point. A point can best be located by two intersecting lines.

The center of a circle must always be located by two intersecting lines. These lines are most frequently at right angles but may intersect at any angle. The type of line used is the center line.

Study the problems involved in drawing three views of a block with a hole through the center of it. (See Figure 39.)

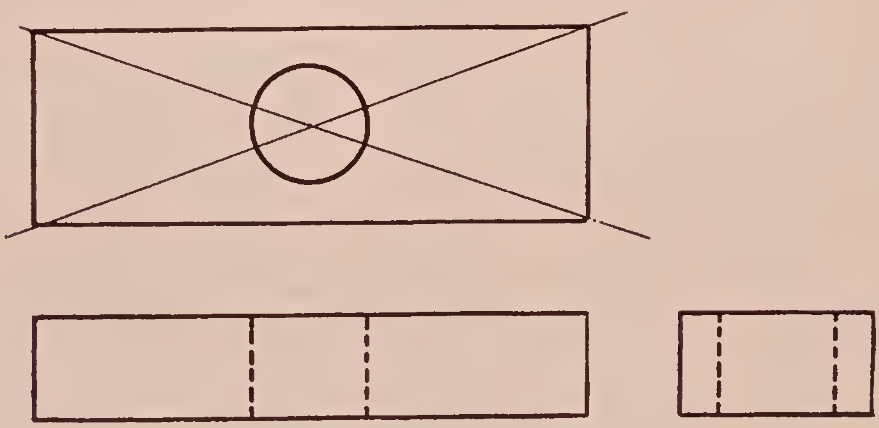


Fig. 39. Locating and representing a hole through a block.

In the method employed in this drawing, the center of the circle is located by drawing the two diagonals of the rectangle.

The center of a rectangle may be located by drawing the diagonals. The center is the point of intersection of the diagonals. After the diagonals are drawn, the circle of the

desired diameter is drawn. Circles are drawn with a compass. The usual drawing set has a compass made up of several parts. As shown in Fig. 40, they are: 1. Compass with divider points; 2. Pencil attachment; 3. Inking attachment; 4. Extension bar for drawing large circle.

The lead of the compass should be sharpened by grinding it on a sanding pad as indicated in Fig. 43. In adjusting the pencil compass for drawing circles, be sure that the lead and metal points are even, or that they are the same length.

Fig. 40. The parts of a compass.

When setting the compass to size, set the metal point in any inch mark on the scale and then set the pencil point in the calibration representing the correct distance. (See Figure 41).

In drawing a circle with pencil or with ink, move the

Photo 41. Setting compass to size prior to drawing a circle.

point clockwise in direction. Grasp the knurled or ribbed point of compass between thumb and first finger of right hand. Guide the metal point of one leg of compass to correct point formed by two intersecting lines, press the metal point lightly into the paper and draw circle by leaning top of compass forward and allowing weight of leg containing pencil point to drag on paper.

Photo 42. Method of drawing circle.

For small circles, the bow compass is provided. This is made in two separate compasses (See Fig. 43), one for penciling and the other for inking. In Figs. 39 and 44 after the circle is drawn in the top view, the sides of the hole are located in the front view by projecting from the sides of the circle in top view. The sides of the hole in the right end view may be measured.

Two center lines are always used to located the center of the hole, or circle. These center lines should be drawn so that they extend beyond the circle about ½″. The centers of

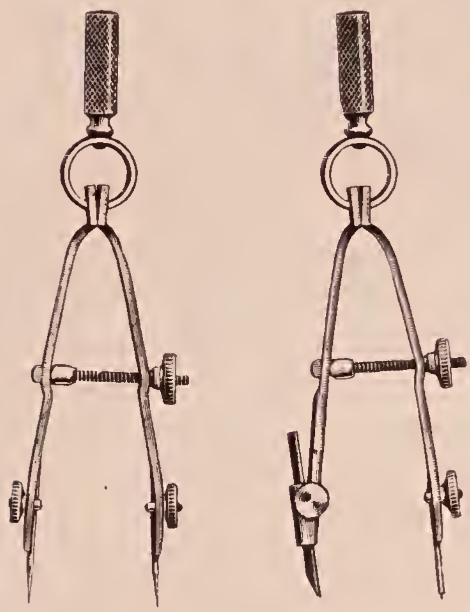


Fig. 43. The bow compass pencil and inking for drawing samll circles.

all holes through the other views are located by center lines extending ½″ outside the view. (See Figure 44.)

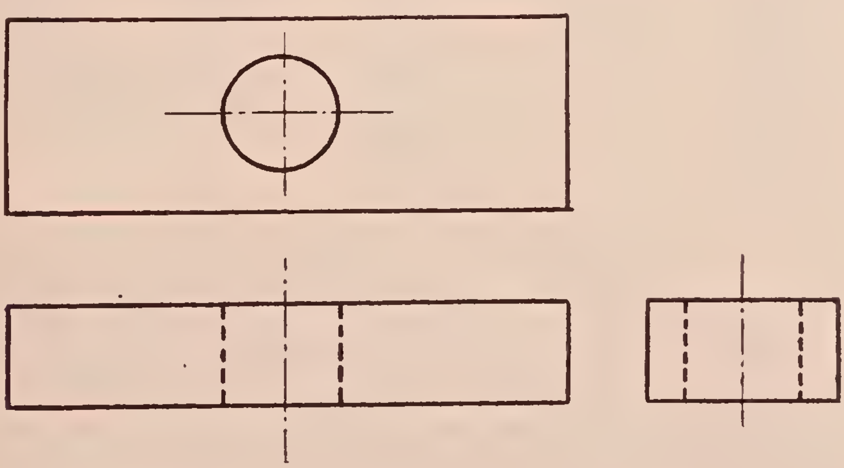
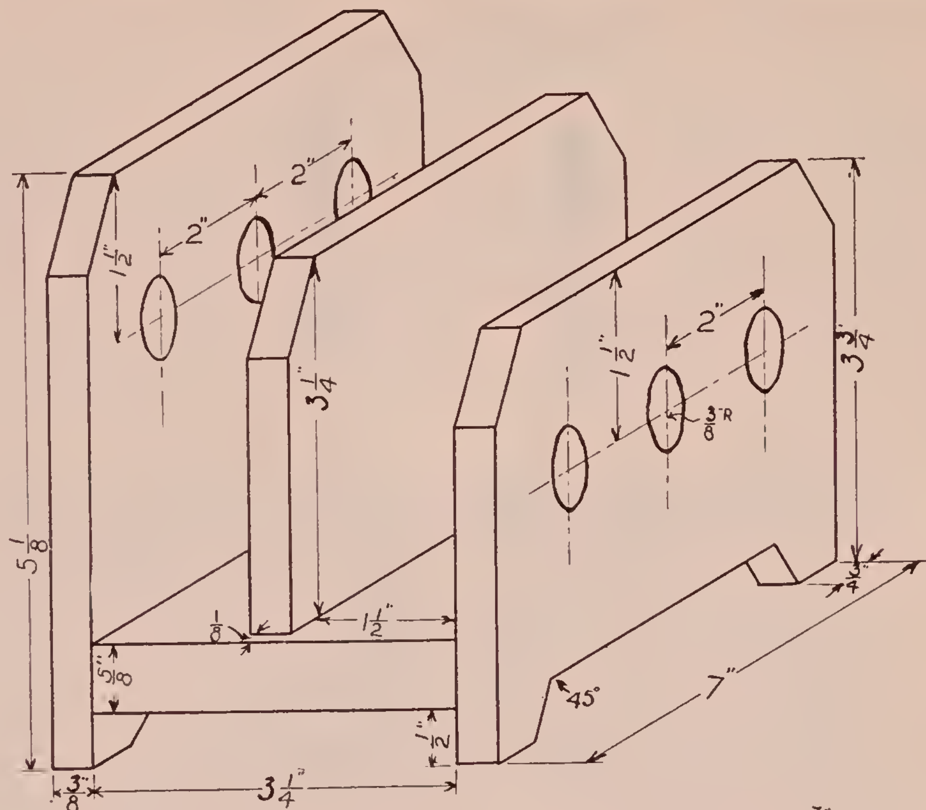


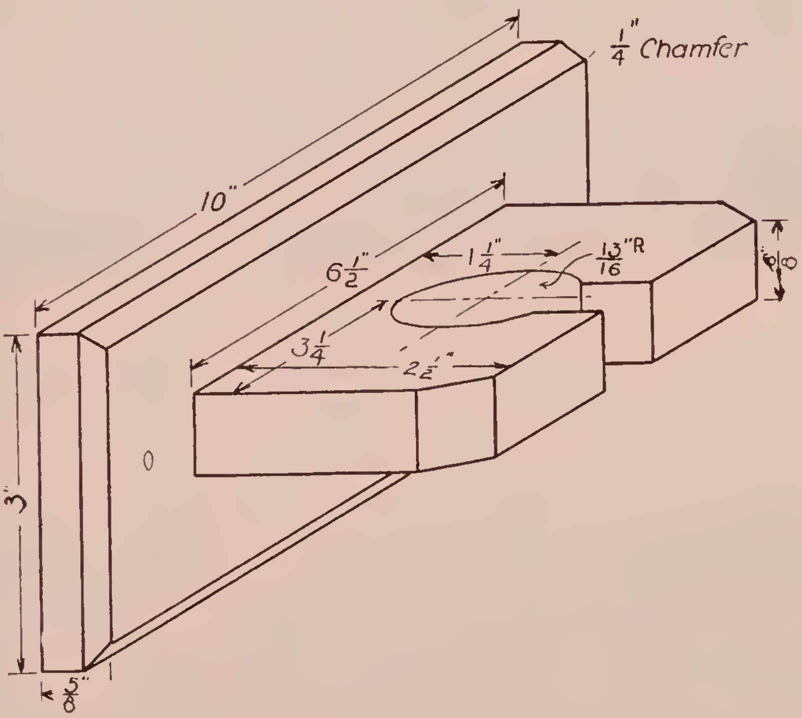
Fig. 44. Showing correct use of center lines, when representing a hole in or through an object.

Drawing No. 8. Draw two views of any problem not already drawn from Plate VIII. (Do not dimension.)

Drawing No. 9. Draw two views of either problem on Plate IX.



A LETTER HOLDER - CORNERS CUT OFF 3/4"



A BROOM HOLDER CORNERS CUT OFF 3/4"

Plate IX. Shop Models.

CHAPTER XI

Inking the Letters on the Sheet.

After five or six sheets have been completed in pencil, time may be taken for a study of inking the letters on the drawing. In order of inking found in the Chapter XV it is seen that letters may be inked first or last. As the classwork progresses some students will complete their work faster than others. These may be set to inking the letters on sheets already finished.

For inking letters a rather fine pen is used. The Gillott No. 303 is recommended as being suited to this type of drawing course. The sheet need not be fastened to the board but

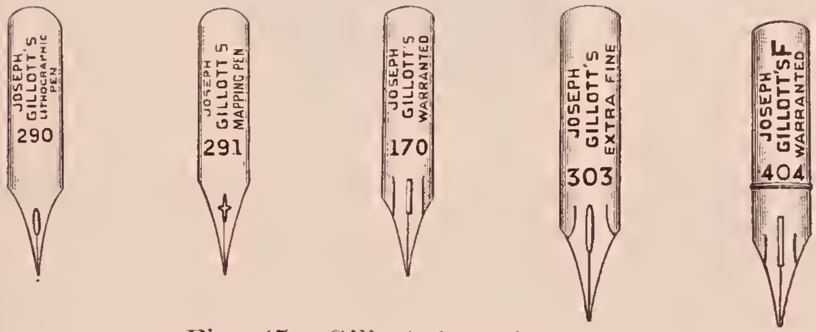


Fig. 45. Gillott lettering pens.

should be turned to a convenient position so as to facilitate inking. The ink used should be some type of water proof black or Indian ink. There are several brands of drawing ink, but all of them come in similarly shaped bottles. The stopper of the bottle has a quill projecting from its center into the ink. The bottle should be fastened down on the drawing board or table to prevent its being spilled by being upset. The pen staff should be fairly small, so that if it is pushed into the bottle it will not rub against walls of bottle neck. The new pen should be smoked so it will retain ink. It should not be heated red hot because this will *draw* the temper. *The lettering pen should be filled with the quill in the bottle stop-*

per. It should not be dipped into the ink bottle. (Fill it same as for a ruling pen, see Figure 55a). Hold quill and pen over the bottle so that any stray drops of ink will fall into the bottle.

Fig. 46. Water-proof drawing ink.

After the pen is filled with ink, a medium sized drop being held on the lower face of pen,the letters are inked. When inking with lettering pen, follow these general rules:

All vertical or slightly sloping lines are inked with one stroke, from top to bottom. (See Figure 47).

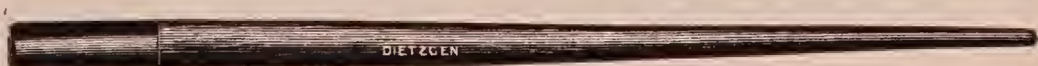


Fig. 46. Thin pen staff for lettering.

All horizonal lines are inked from left to right.

All circular letters and figures are inked with two strokes, the first beginning at top right hand and finishing at bottom left hand corner, the second stroke beginning at top right and proceeding downward to complete the letters. All partial circular letters and figures are completed the same way.

All parts of letters must be of same weight.

Do not use a blotter over letters after they have been inked. Allow ink to dry and it will be blacker and more

permanent. Do not attempt to erase guide lines until several hours of time have elapsed. Then erase very lightly with point of eraser. Do not rub over letters until the ink is partly removed. Guide lines should be easily erased; then the letters will not be dimmed in the process of erasing.

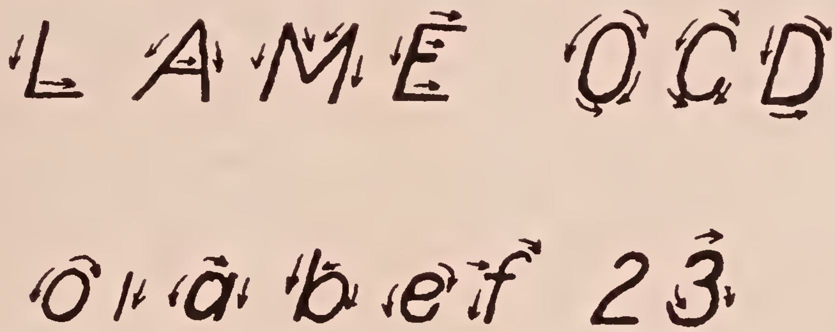


Fig. 47. Order of strokes in inking letters.

The lettering on all of the sheets drawn up to this time may be inked before more sheets are made, if it is found desirable to do so.

CHAPTER XII.

LETTER SHEET.

A formal letter sheet affords good practice in penciling and inking freehand letters. The letter sheet should not be too complicated but the product should be an accurate gage of the ability of the student. In a mechanical drawing course, no work should grade under 90%; indeed it should be even better, for acceptance. The learner must make sheets over until they are worth at least 90%. By keeping the difficulty of the assignment within the ability of the student, this standard of accuracy may be maintained.

Practice lettering pads may be obtained from publishers and manufacturers of drawing instruments. (See Figure 48.) These pads are most frequently lined with three guide lines, the bottom space being twice as large as the top. Another size of lower case is made by making this bottom space 3/32″ and the top space equal to half of this amount.

Two letter sheets are given, Plate X and XVI. One is to be made at this time in the course; the second is to be made

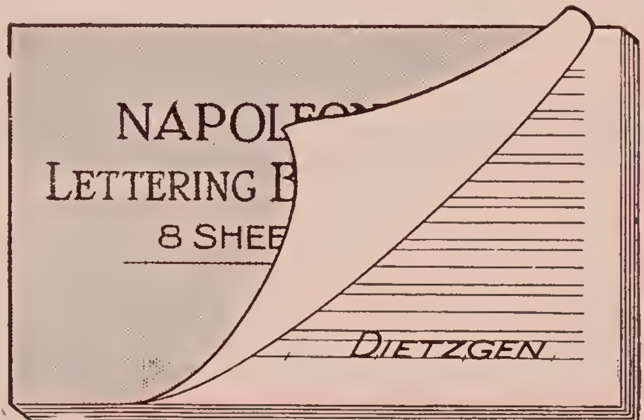


Fig. 48. Practice lettering guide sheet pad.

at the beginning of the second term or year of drawing. It is a splendid practice to start each term's work with a letter

sheet. The second letter sheet includes a simple type of block letters and it should be made only after more experience has been gained by the student.

There are many kinds of mechanical letters. Those made on squares laid out on the paper are called Block Letters. The simplest form of block letters is the one five blocks high and three blocks wide. All corners are cut off at 45° and slope lines are all of a uniform slope. The letters i, m, and w, are one, four, and five spaces wide. When the a and v or w are adjacent, the space is closed up one space. The block letters may be outlined, inked solid or shaded 45° to top right or bottom right.

Block letters or other forms of mechanical letters are used on display drawings and cover sheets. Ability to do fine decorative lettering requires and denotes a considerable artistic ability.

Drawing No. 10. Lay out the letter sheet as indicated on Plate X. The guide lines and slope lines must be drawn very lightly. If they are heavy, dents will show in the paper after the erasing is done and in erasing, the letters themselves will be blurred. Fill the first and fourth lines from left 2″ border to right 2″ border with Upper Case alphabets; the second and fifth with Lower Case alphabets and the third and sixth with figures and fractions. In the last line, print in lower case letters a motto such as: "The ability to do good lettering may be gained by practice." The name of the sheet *lettering* is placed in the top space.

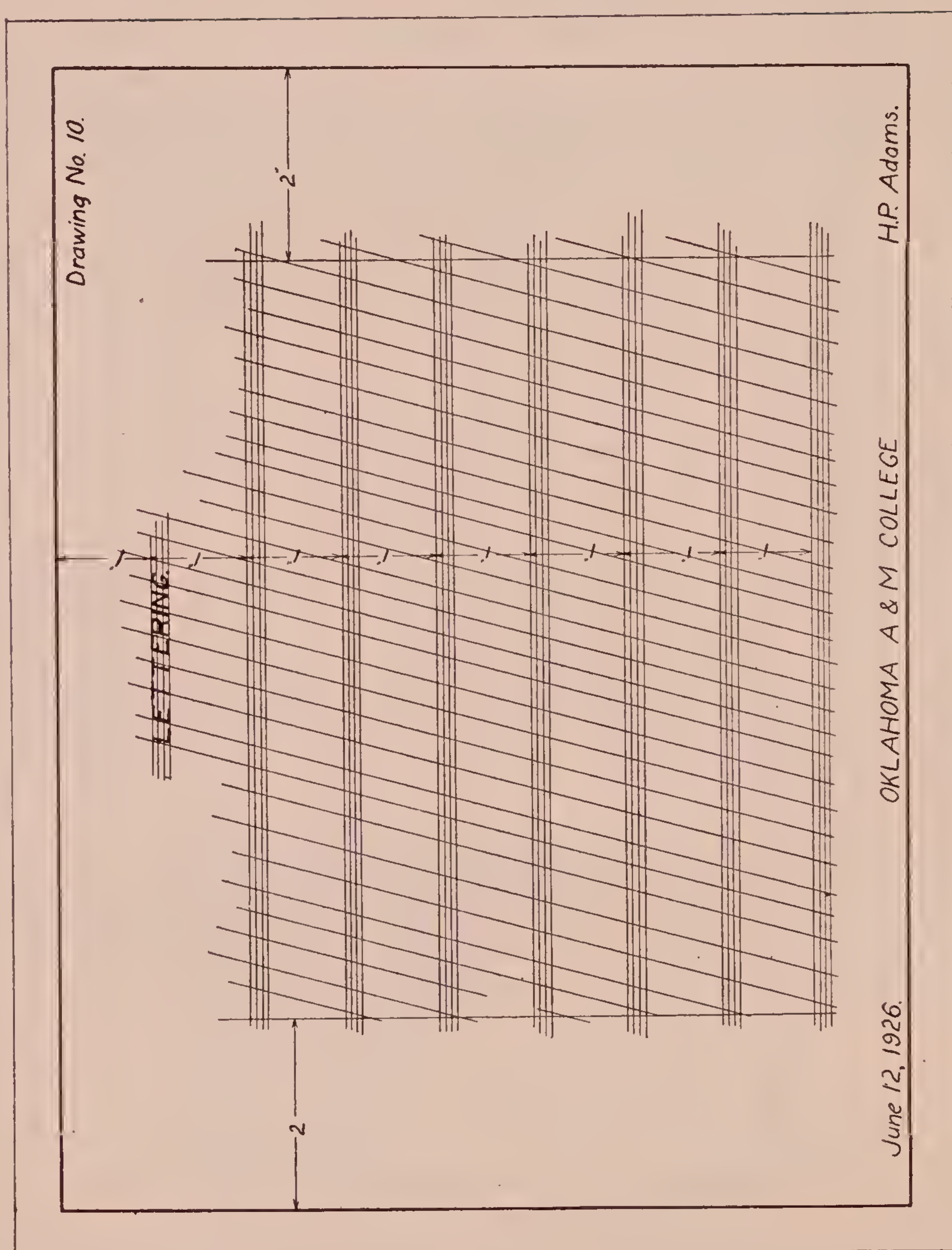


Plate X. An easy practice letter sheet.

CHAPTER XIII

Cylinders

Rectangular solids have six views. Cylindrical solids likewise have six views. It is more difficult to visualize these six views, but if cardinal directions are used, we have North, South, East and West; then top and bottom, giving us six directions for looking at the object and thus six views. In figures 49 and 50 are shown six views of a cylinder, first with axis vertical, and second with axis horizontal.

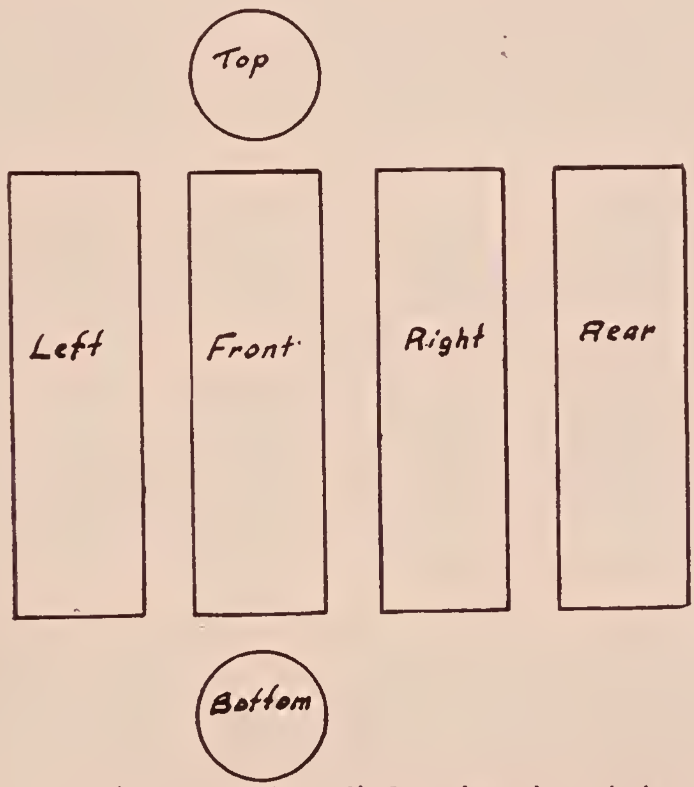


Fig. 49. The six views of a cylinder when the axis is vertical.

In either case, it is observed that one shape is repeated twice and the other is repeated four times. This makes it unnecessary to draw all six views. Even three views would repeat certain shapes twice, so that this rule may be given:

A cylinder may be represented by two views. When the

axis is vertical, draw the top and front views; when the axis is horizontal, draw the front and right views. (See Figure 51.)

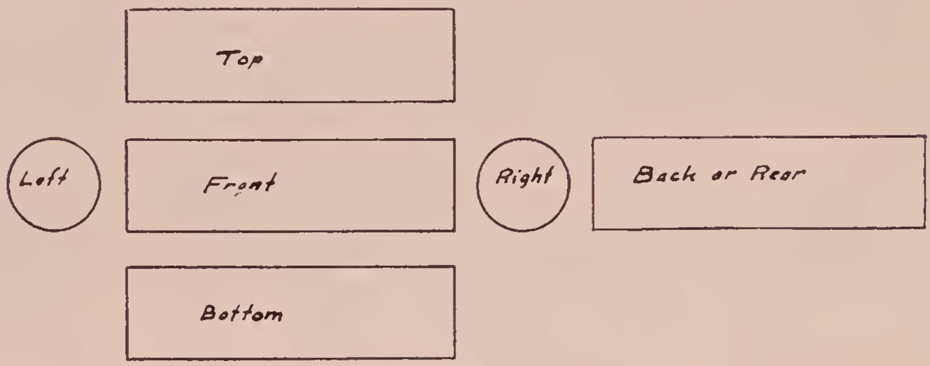


Fig. 50. The six views of a cylinder when the axis is horizon al.

Cylinders are formed in several ways. In considering geometrical cylinders, a plane 1″x5″ when revolved about one of the long edges, forms a 2″x5″ cylinder. Or a 2″ circle, if moved 5″ in a direction perpendicular to its surface, will form a 2″x5″ cylinder. In the shop, cylinders may be turned in the lathe. The rough stock is turned to a perfect diameter and the ends are cut square. Shafting and wire are formed by soft metal being forced or drawn through a round hole. However, the most common conception of a cylinder carries with it the idea of revolutions about an axis. The earth revolves

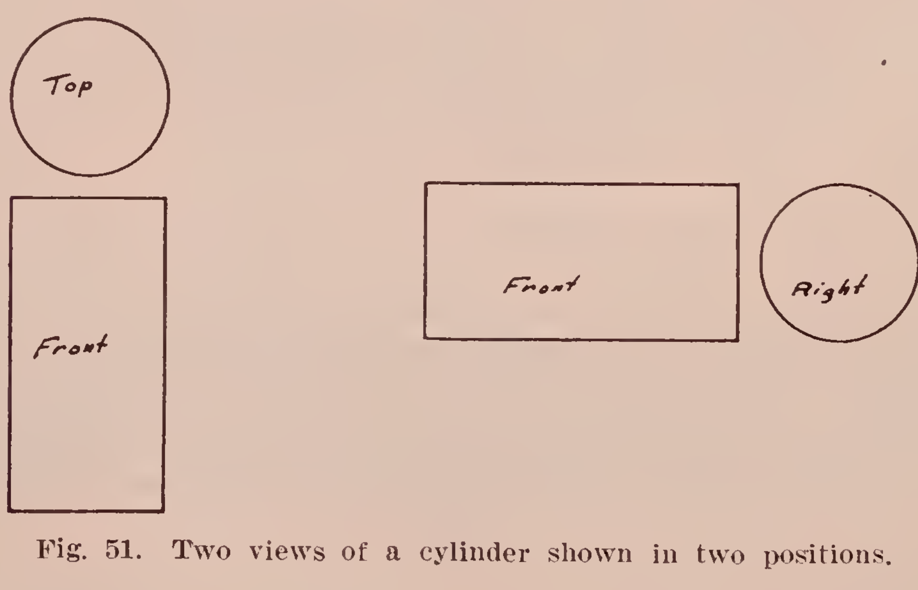


Fig. 51. Two views of a cylinder shown in two positions.

on its axis, the axis of rotation passing through the north and south poles. The axis or revolution is present in drilled holes, cylinders of engines and in many types of cylindrical forms.

The axis of revolution of a cylinder is always drawn and is represented by long and short dashes. This line is called the center line.

The end view of a cylinder is always a circle. The center of this circle is always located on the drawing by two intersecting center lines.

The preliminary sketch of the cylindrical form drawing should show the proper selection of views and also the correct use of center lines. Figure 52 shows a hollow cylinder of which the front and right views have been sketched. After the

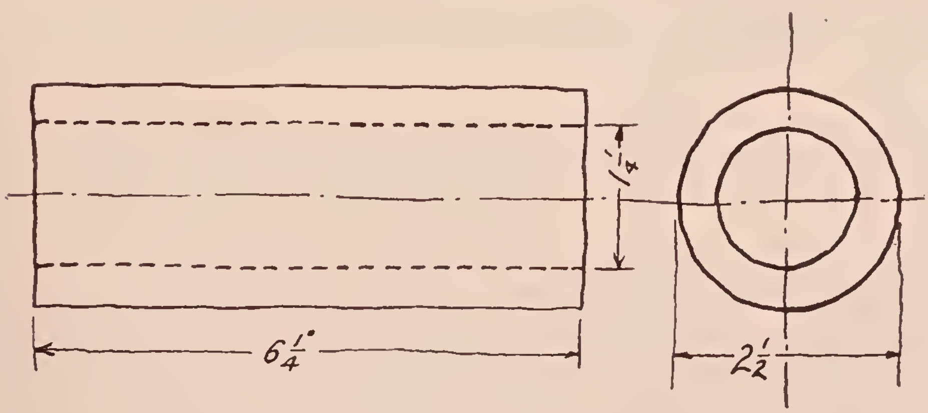


Fig. 52. Preliminary sketch of front and right views of hollow cylinder

sketch is made and dimensions are placed on the sketch, the spacing should be figured. In addition to the regular spacing as has been figured for earlier sheets, the distance to all center lines from the nearest border line must be given.

Indicate distances from all center lines to the nearest border line by dimensions in a circle. The sketch shown in Fig. 53 is of the correct type. When the student has the sketch this far along, the instructor should check it and okeh it so the pupil can proceed with the drawing.

The order of drawing the pencil lines on a drawing of a cylinder is very definite. Center lines should be located rath-

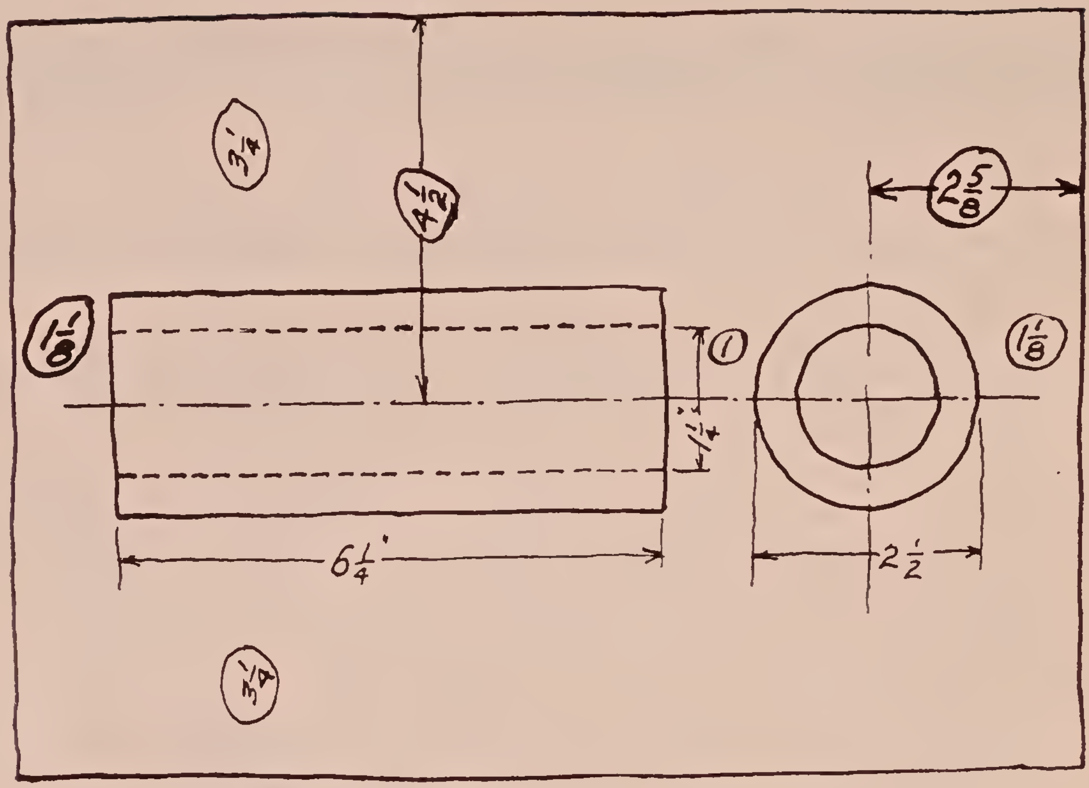


Fig. 53. The same sketch showing the amount of spacing and location of center line.

er than the edges of circles. Figure 54 shows the order of drawing the pencil lines of the drawing shown in the sketch solved in Figure 53. The procedure is as follows:

1. Locate position of horizontal center line by measuring $4\frac{1}{2}''$ down from top border line.

2. Locate the two vertical lines in front view and the vertical center line by measuring $1\frac{1}{8}''$ and $6\frac{1}{4}''$ from left border and $2\frac{5}{8}''$ in from right border line. These measurements should be made without moving scale.

3. Draw pencil lines 1, 2, 3, and 4 in this order. Draw center lines of long dashes and short dots.

4. Draw the two circles.

5. Project from top and bottoms of circles as indicated by the arrows and draw lines 7, 8, 9, and 10.

Any great divergence from this order of drawing the pencil lines of this drawing will result in loss of effort. Any

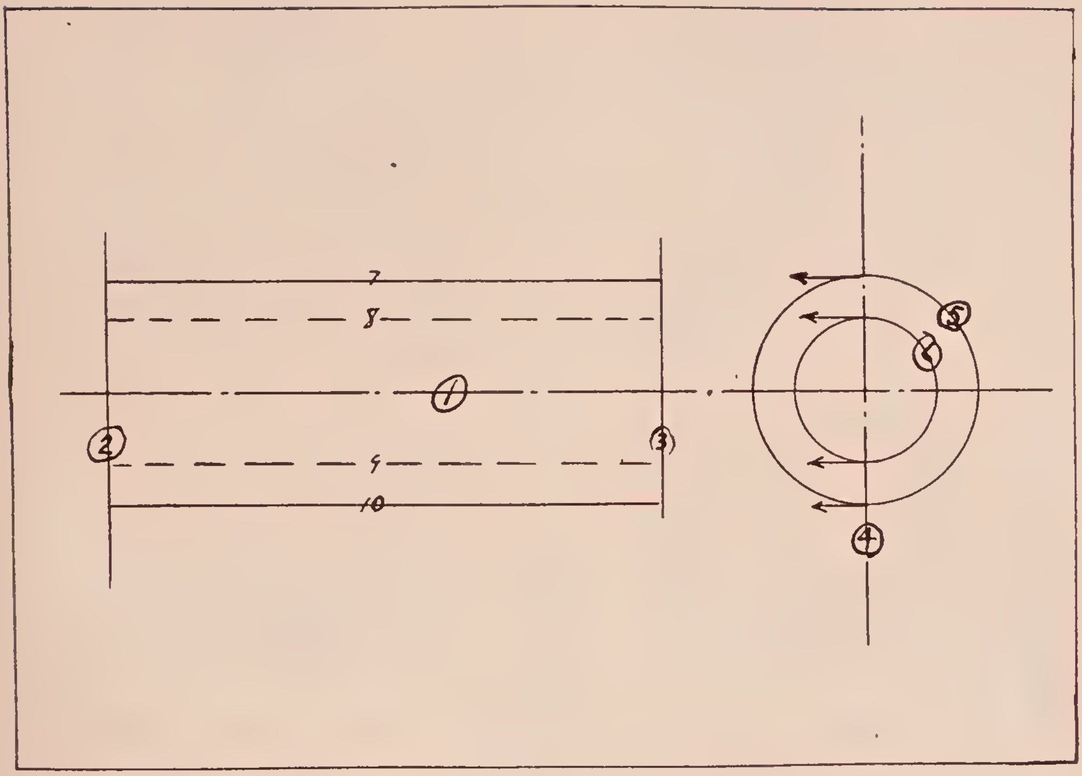


Fig. 54. Order of drawing lines of drawing of a hollow cylinder.

time spent in locating lines 7, 8, 9, and 10 by measurement is wasted. Similarly, time consumed in locating the edges of the circle is largely lost. Furthermore, in all drawings of cylindrical shape, it is best to follow this order of procedure. This is undoubtedly "the one best way."

Drawing No. 11. Draw two views of any problem on Plate XI.

Drawing No. 12. Draw two views of any problem on Plate XII.

Drawing No. 13. Draw two views of any problem on Plate XIII.

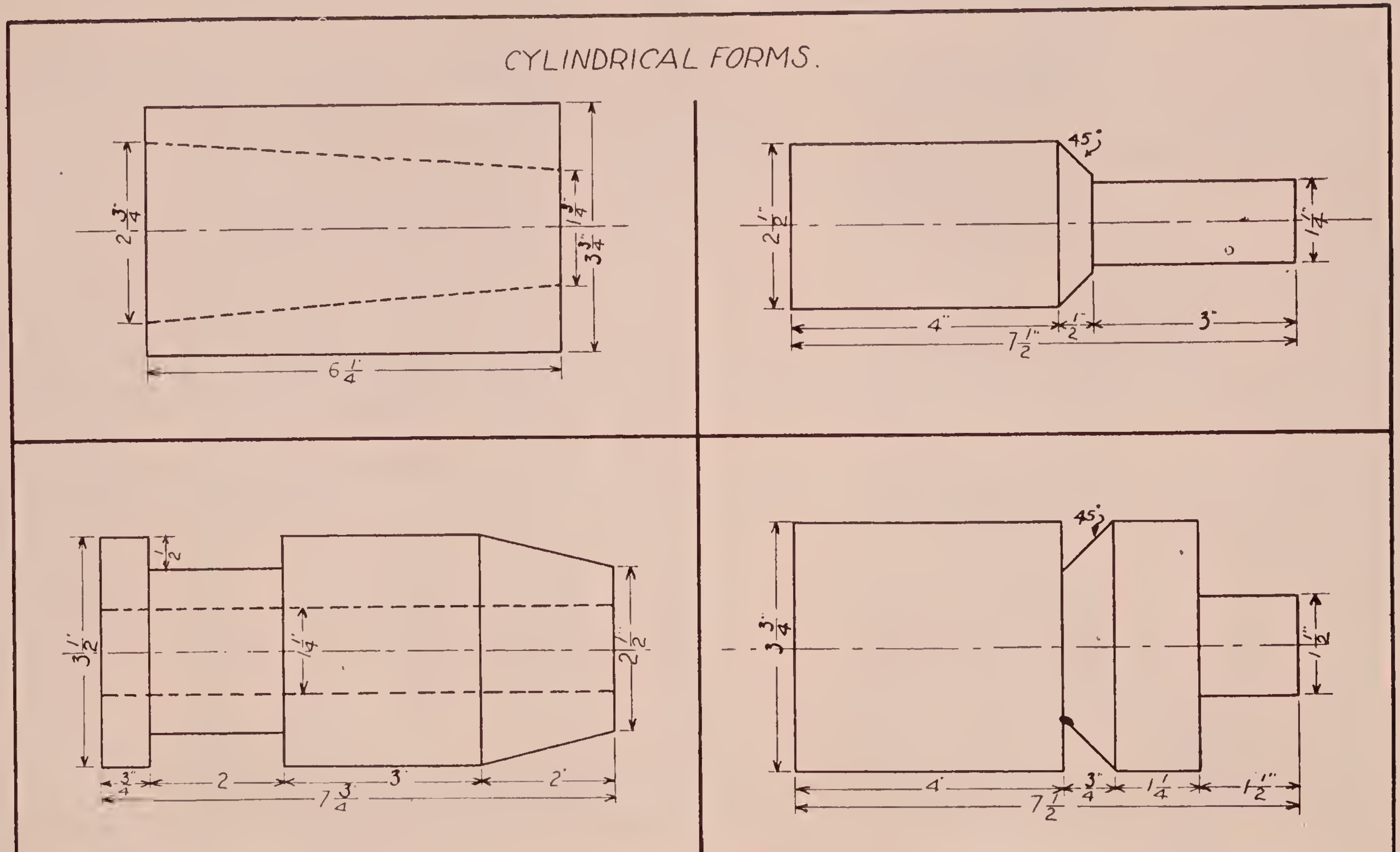


Plate XI. Cylindrical shaped problems.

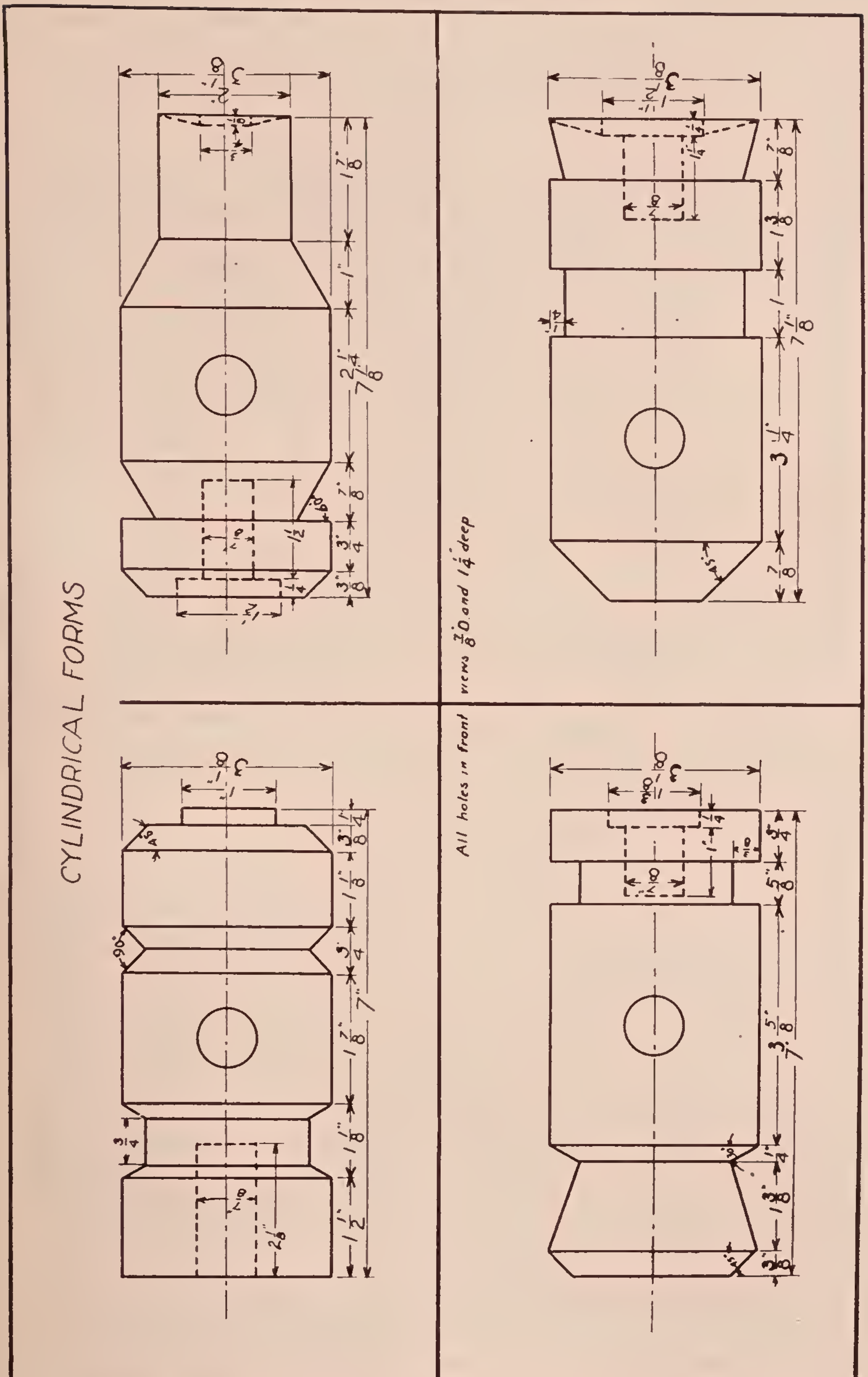


Plate XII. More cylindrical forms.

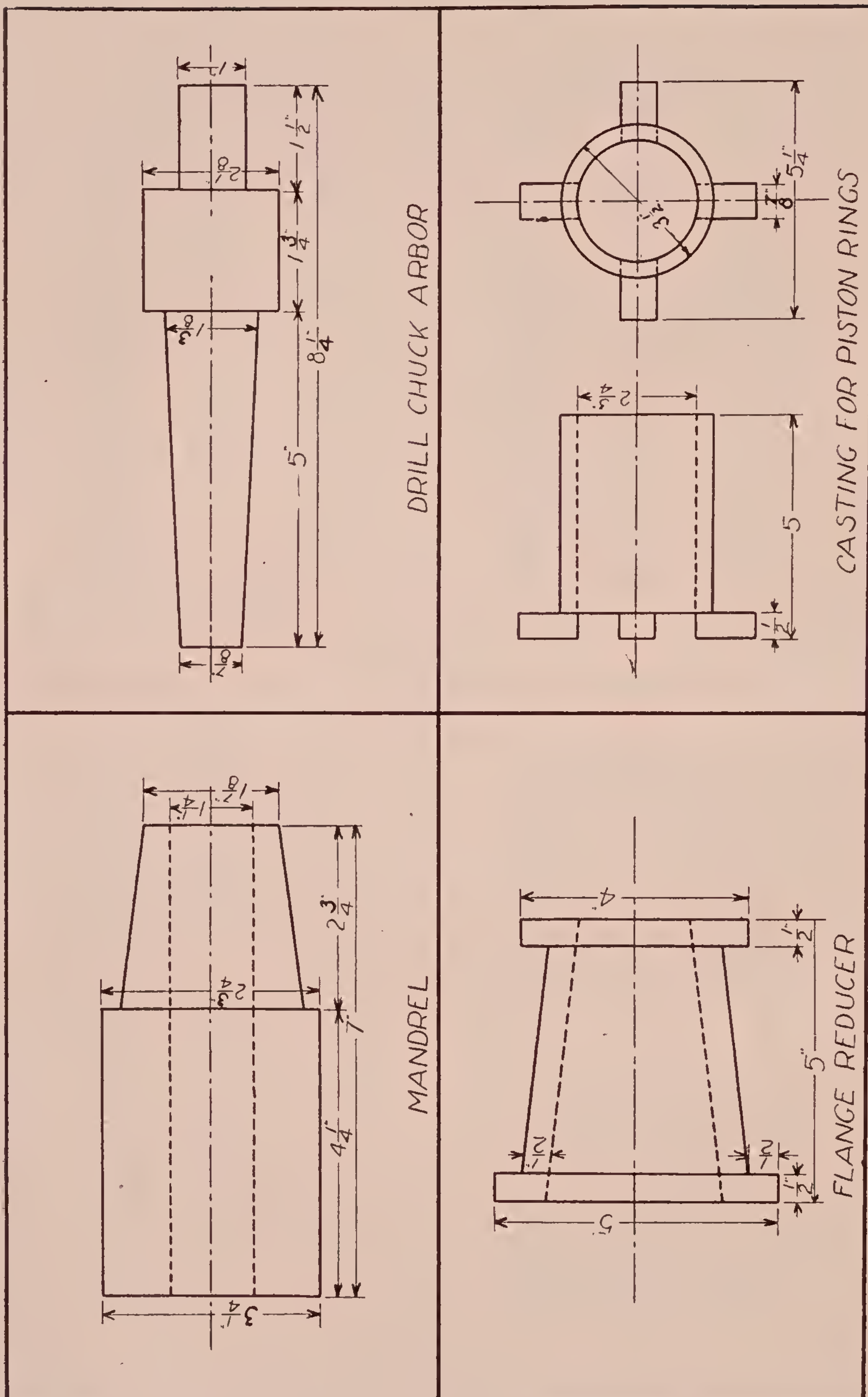


Plate XIII. Cylinder problems.

CHAPTER XIV

Dimensioning

The purpose of dimensioning the drawing is to make it possible for the workman to make the object from the drawing. Therefore, all necessary dimensions must be given and with great clarity and accuracy. The following rules are given as a help in dimensioning the drawing:

1. *Place dimensions below and to the right of the views when possible.*

2. *Place an equal number of dimensions on each view when possible.*

3. *The first dimension line should be at least 1/4" from the drawing and other dimensions should be the same distance further away.*

4. *Termination lines should not touch the drawing. Leave a space of 1/16".*

5. *Termination lines should extend 1/8" beyond the last dimension line.*

6. *Figures should read from bottom of sheet on all horizontal dimensions and from the right end of sheet when dimensions are vertical.*

7. *The bar of all fraction should be in line with the dimension line and should be inked with the ruling pen when dimension line is inked.*

8. *The number of degrees in an angle should be given in an arc of a circle.*

9. *Arrow tips should be sharp but not too long or conspicuous.* (Arrow tips may be inked with ruling pen and triangles, sides of arrow forming an included angle of 30°.

10. *Termination lines should never cross dimension lines and vice versa.*

11. *Angular distances must be given on a radius of a circle.* (See 1¾" Plate XIX.)

12. *Dimension lines and center lines should never coincide.*

13. *Figures should not be placed on a center line.*

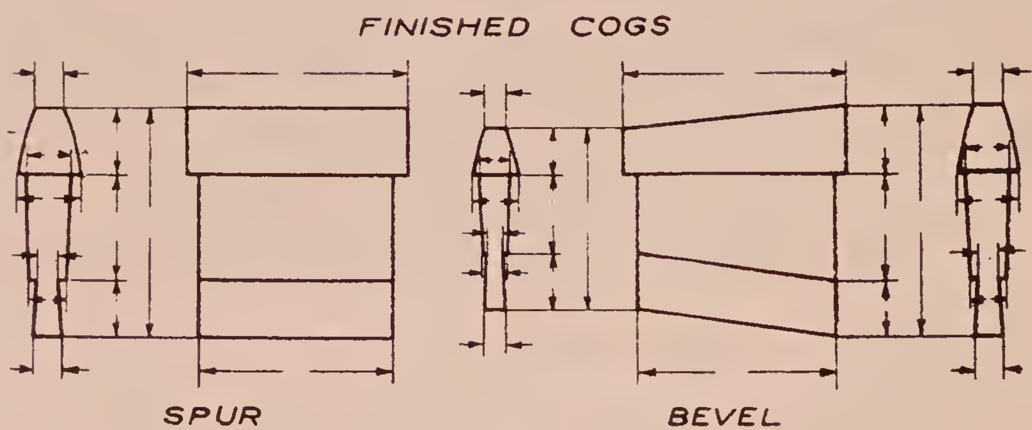


Fig. 55. A commercial drawing from a MEDART catalog showing the placing of dimensions and dimension lines.

Figure 55 shows two drawings from a Medart catalog with dimension lines placed for customer to fill in. Note that termination lines touch the drawing. Also that lines connect the views. Our rules of dimensioning do not advise these

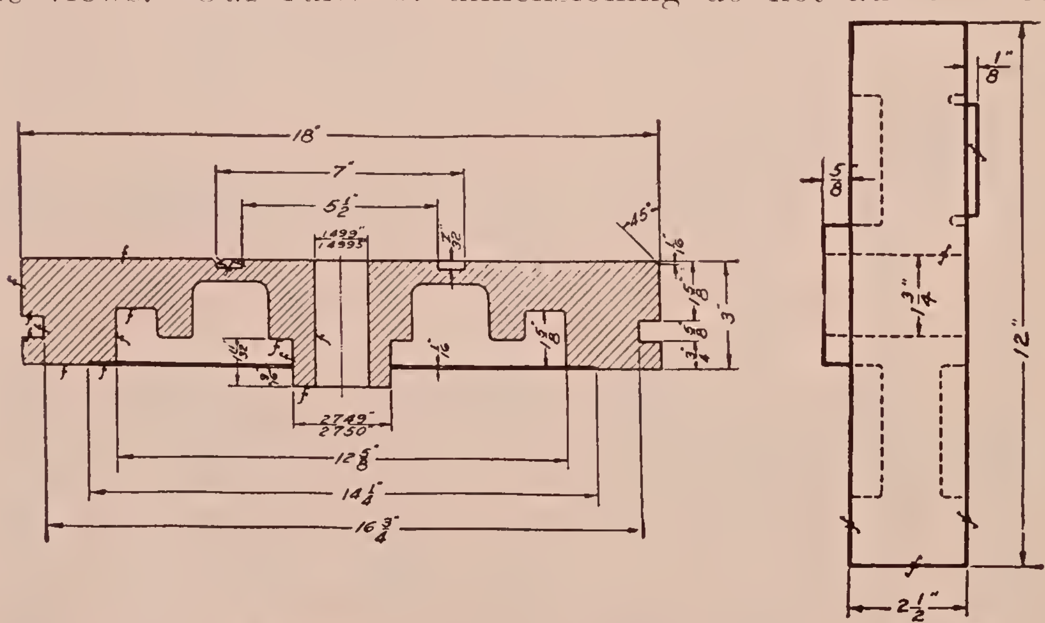


Fig. 56 Commercial drawings from advertisements in American Machinist showing location of dimensions.

methods, yet this is a splendid example of commercial drawing.

In Figure 56 two drawings are shown bearing out most of the rules given above. Figure 57 shows a drawing in which several rules of dimensioning are violated. Figures on vertical

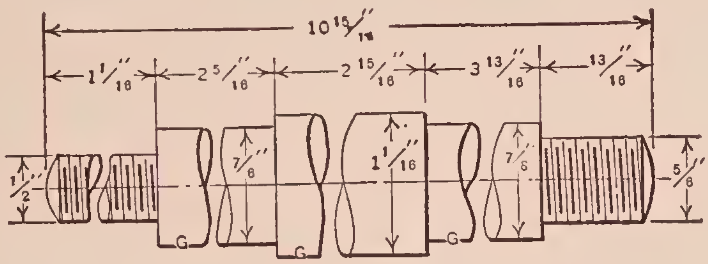


Fig. 57. A drawing poorly dimensioned.

dimensions do not read from right. This rule is not so inviolable as some others. The bars of the fractions are not in line with the dimension lines so that 1-1/16 might be mistaken for 11/16 or 13/16 might be interpreted as 1-3/16.

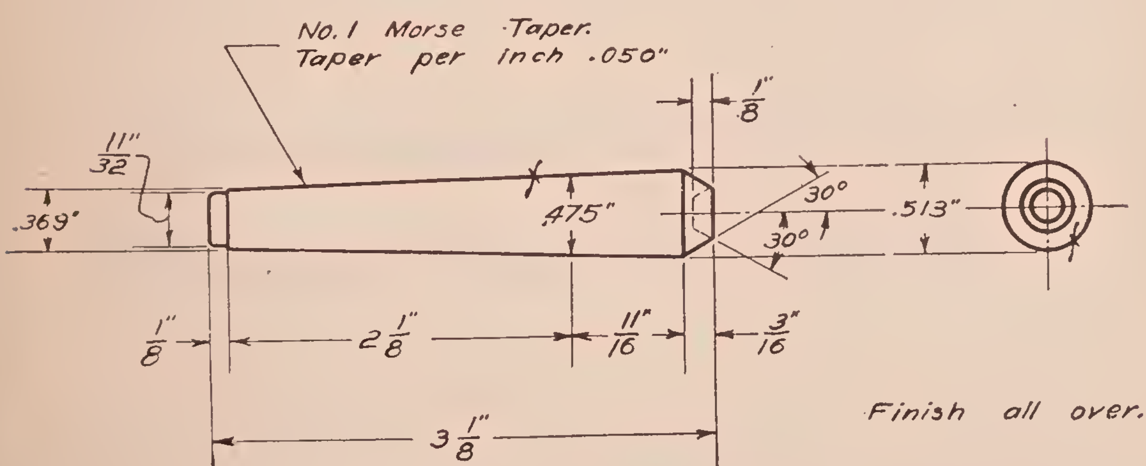


Fig. 58. A cylinder drawing with dimensions. (From South Bend Lathe Book).

Figure 58 shows a drawing taken from a South Bend lathe instruction book which is well dimensioned. The bars of fractions have been made freehand and vertical dimensions read from the bottom but these are not severe mistakes.

Figure 59 shows the correct method of dimensioning cylin-

der drawings for this text. All rules of dimensioning are observed.

Drawing problem. Dimension at least four of the six sheets previously drawn.

CHAPTER XV

Inking the Drawing

This is a very important part of the work of making a drawing. Pencil drawings are frequently made and are not inked, the drawing being worked from by the craftsman. This occurs in cabinet and mill works where full size details are often made for the use of the worker. On the other hand, many drawings are made in pencil and tracings are inked direct from the pencil drawings. This is true of all work where several sets of blueprints are necessary for competitive bids. In such cases the pencil drawing is not inked. But in most school work all pencil drawings are inked. This gives the student inking practice for later work in making tracings.

The instruments most commonly used for inking are *the ruling pen* and *the inking compasses.* Ruling pens come in several sizes, all sizes being used essentially the same way. It is best to practice drawing lines on scrap paper.

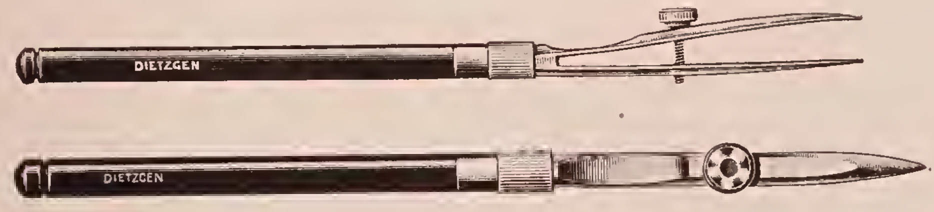


Fig. 59. Two sizes of ruling pens.

Fill the ruling pen by touching the quill in the stopper to the inside part of the points of the ruling pen. Hold the little fingers of the two hands together. Hold the ruling pen in left hand and the bottle stopper in right. (See Figure 59a). Do not fill the pen too full. Do not fill the pen over the sheet; the correct place is directly over the bottle. Do not put any ink on outside of nibs of ruling pen. If any ink should be discovered on the outside, wipe it off with soft cloth. Do not

leave stopper out of bottle. The ink solvent will evaporate rapidly. The ink bottle should be fastened to table to keep it from upsetting.

Fig. 59a. Filling a ruling pen.

Lines are always inked from left to right on top edge of the square and from bottom to top on left edge of triangle. The screw head of the ruling pen is always held on

Fig. 60. Inking horizontal lines with ruling pen.

the outside of the straightedge. The pen is held perpendicular to the paper, but leaning in the direction of motion.

Ink all lines of the same weight before changing setting of ruling pen. Thus, all border lines are inked, then all outline lines of the drawing and then all of the lighter lines. In this text only three weights of lines are given. Many texts give four and some give more than four. In many texts the invisible lines are somewhat lighter than outline lines, yet invisible lines are outline lines and may be made the same weight. Each drafting room has its own rules about weight of lines, conventions, etc.

Fig. 61. Inking vertical lines with ruling pen.

Lines are always inked from left to right on top edge represent different things in mechanical drawing. A complete set of lines with an explanation is called an alphabet of lines. The order of inking lines should be as follows:

1. *Border lines.*
2. *Circles and arcs of circles.*
3. *Irregular curves.*
4. *Horizontal outline lines, beginning at top and inking all horizontal outline lines including invisible lines.*
5. *Vertical outline lines, beginning at left and inking all*

vertical outline lines, including invisible lines and proceeding toward right.

6. *All oblique outlines.*
7. *All horizontal dimension, termination and center lines.*
8. *All vertical dimension, termination and center lines.*
9. *All cross section lines.*
10. *Lettering. (This may be done first if desirable.)*

When inking circles, set the point of the compass the same length as the pen. Fill the pen and try drawing a circle on scrap paper the same size as the required circle. When the circle is large, bend the two legs of the compass so that they are parallel. Always ink circles in a clockwise direction, holding the compass by the knurled tip. (See Figure 62). Let the weight of the compass be the pressure applied.

Fig. 62. The position of compass and hand when inking a circle.

Should smears or blots result, the sheet should be made over. No erasing of ink is permissible. In case ink is to be

removed a sharp round-pointed knife is used and the ink is shaved off. This is not to be encouraged. It is better not to make mistakes.

After inking has been done, let the sheet dry for several hours before cleaning. Erase all extra pencil lines with high grade pencil eraser, then clean sheet with some soft cleaning eraser. (See Figure 63). Do not rub hard on the paper, and the inked lines will not be dimmed. After the sheet has been cleaned, trim it and file it away.

Fig. 63. A patent cleaning eraser. Not used for erasing lines.

Drawing problem. Ink all sheets made to date. Should blots be made, make the sheet over. Do not ink lettering, guide or slope lines.

CHAPTER XVI

Disc Forms

Disc forms are short cylinders. Take the problem of drawing two views of a 6″ ring made of 1″ square stock. This is really a 6″ cylinder 1″ long and all of the principles involved in the cylinder problems in Chapter XIII will apply.

Many disc forms have holes in groups of two, three, four, six, or eight, equally spaced about a circle. These holes are located by drawing a complete circular center line and then drawing radial center lines across this circle. The radial center lines should project ⅜″ beyond the circle representing the

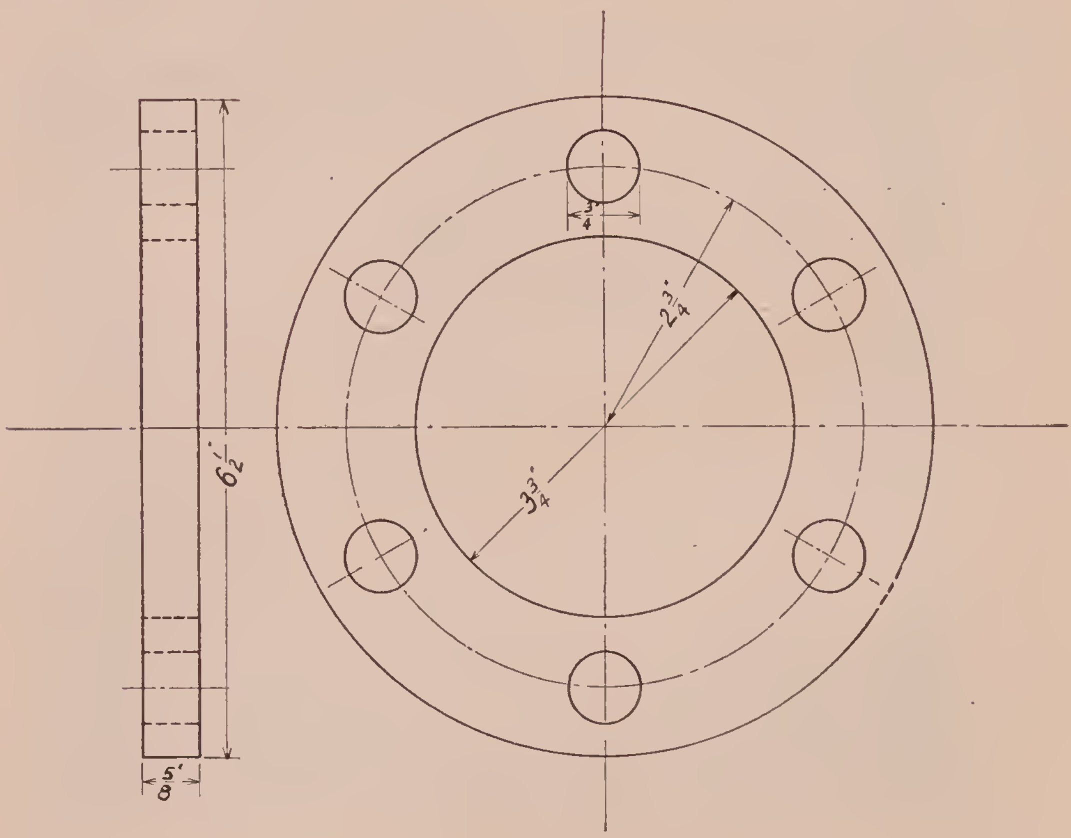


Fig. 64. A circle plate or disc with six holes.

hole. When these holes are spaced equally there is no need for dimensioning the angle of spacing.

Note the method used in dimensioning the disc form drawn in Figure 64.

Drawing No. 14. Draw two views of any problem on Plate XIV. Dimension the sheet.

Drawing No. 15. Draw two views of the truck wheel shown in Fig. 65. Table of various sizes will be found below the figure. Dimension the sheet.

Drawing No. 16. Draw two views of any problem on Plate XV. No dimensioning.

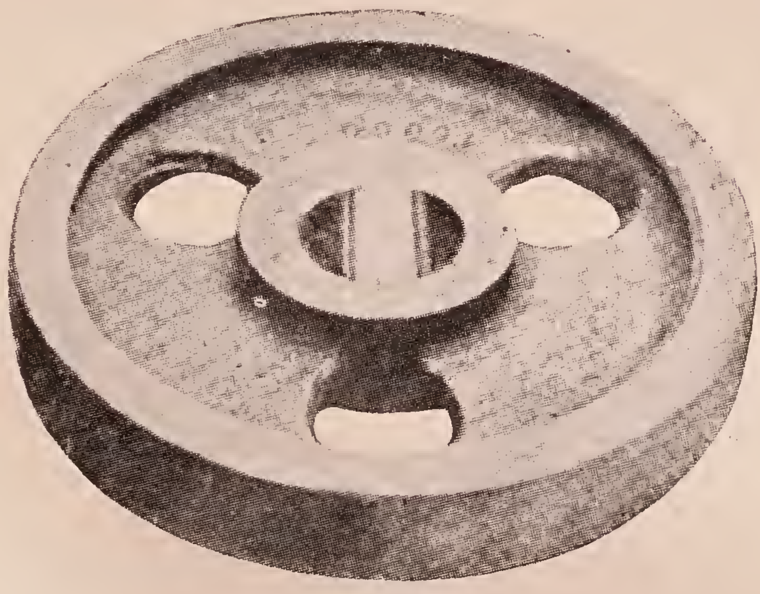


Fig. 65. A truck wheel.

TABLE OF SIZES OF TRUCK WHEELS

DIAMETER				THICKNESS		WIDTH
of wheel	of hub	of hole in hub	of hole in web	of rim	of web	of hub and rim
6"	2¼	1¼	1¼	5/8	5/8	1¾
7"	2¼	1⅜	1¼	5/8	5/8	2
8"	2⅜	1½	1¼	¾	¾	2¼
9"	2½	1⅝	1¼	¾	¾	2½

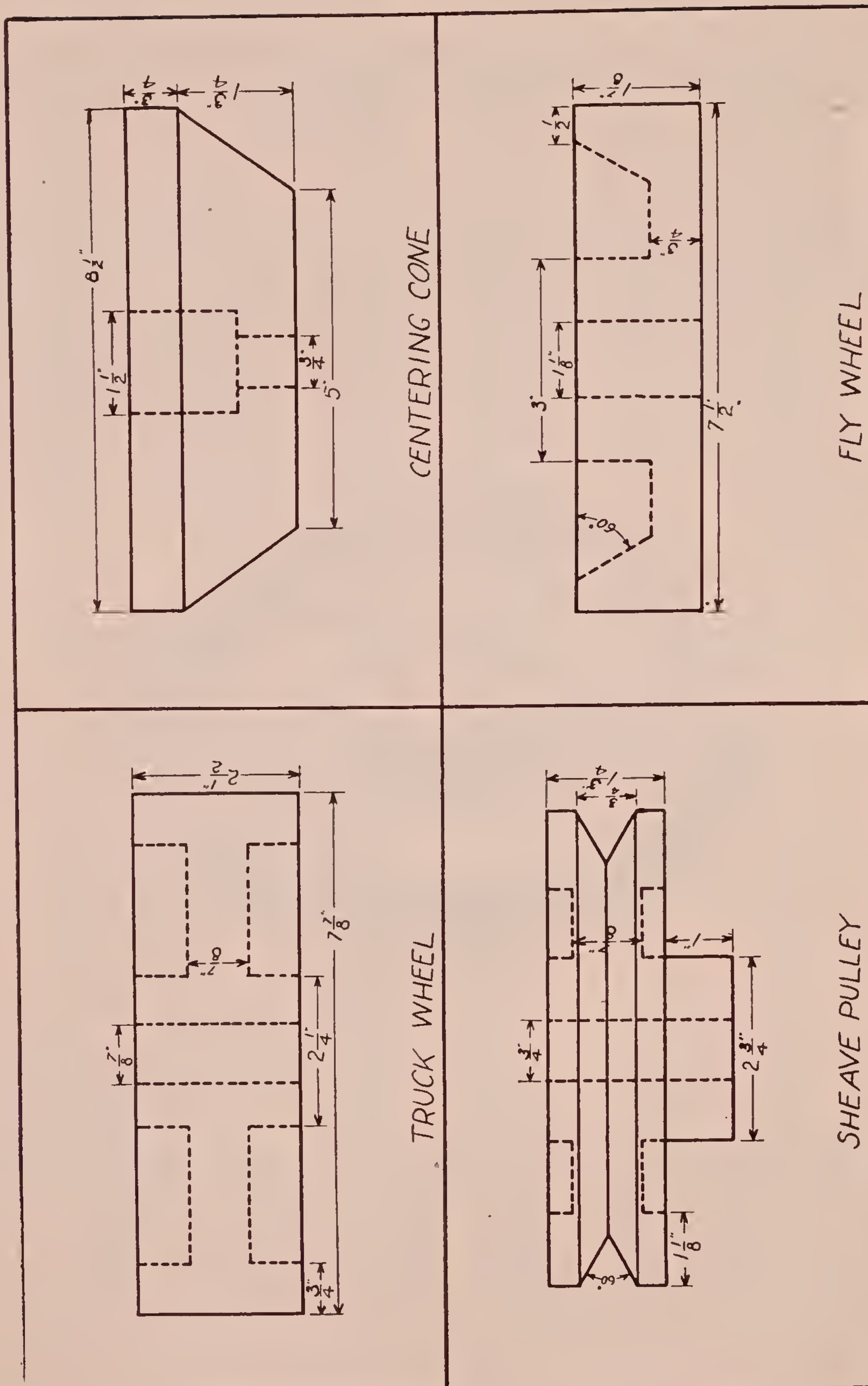


Plate XIV. Disc form problems.

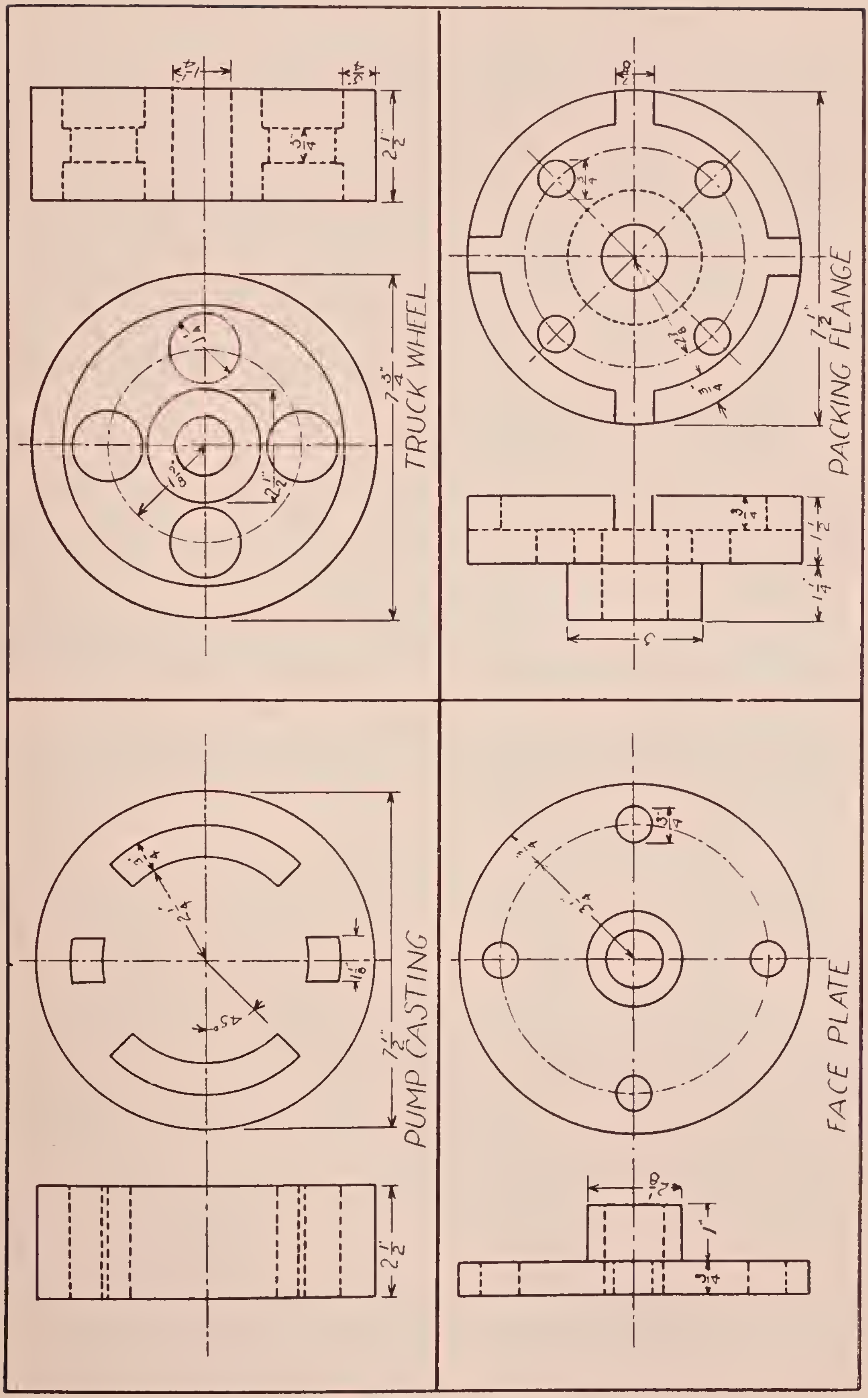


Plate XV. More difficult disc forms.

CHAPTER XVII

Scale Drawing

When an object is too large to be drawn its actual size on the sheet, it must be drawn to scale. For instance, two views of the library table Fig. 69 are to be drawn. The amount of drawing lengthwise of the sheet is 44 plus 28 or 72″. This is to be put in a 12″ space. The drawing could be made 1/7 or 1/8 size.

There are two standard scales used. 1. *In architecture a certain part of an inch is allowed to equal one foot.* 2. *In shop drawings frequently a fractional part of an inch is allowed to equal one inch.* Strictly speaking, the regular scale is designed for use as indicated in (1) only.

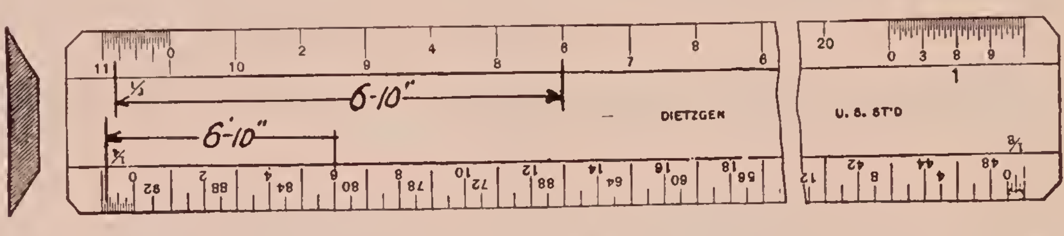


Fig. 66. A scale with four common scales on it, used by architects. Also with the distance 6′-10″ indicated on two scales

Figure 66 shows a style of scale used by architects which has four scales on the top edges: 1/8″=1′ ¼″=1′, ½″=1′, and 1″=1′. Each of these scales except the smallest has the end space divided into twelfths so that feet and inches may be measured. On this scale, the distance 6′-10″ has been indicated on both the ¼″=1′, and the ½″=1′ scale showing the use of the spaces representing feet and the one space divided to allow inch measurements to be made.

Consider the two views of the built-in book case, Figure 67. The entire length of drawings is 13′-1″ and the height is 7′-11″. Using the scale ¾″=1′, the 9″x12″ sheet size becomes 12′x16′, leaving spacing as indicated on Figure 67. The archi-

tect usually uses a large sheet of paper and makes his drawing to a convenient scale, then draws a border outside the drawing. He seldom uses a standard size sheet. A drawing of the floor plan of a large high school measuring 82'x176'

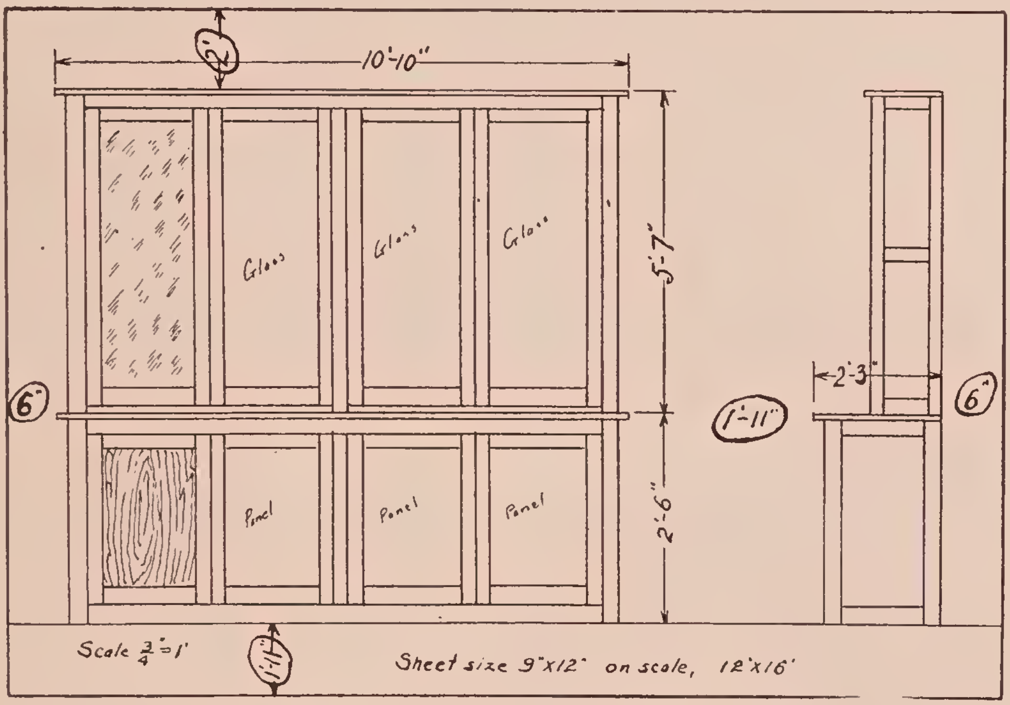


Fig. 67. Spacing for 2 views of built-in bookcase, scale, 3/4"=1'.

feet might be made on a scale of 3/16"=1' or the size of the drawing would be 15⅜"x33". The draftsman, however, would never figure this size, simply taking a sheet of paper large enough to hold the drawing.

Architectural drawings or plans usually consist of several sheets. When the sheet size is determined, all of the different sheets are usually made the same size. In order to facilitate the making of a drawing to scale, a scale guard,

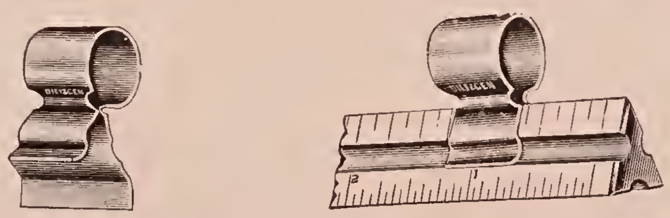


Fig. 68. A triangular scale guard, used when making a scale drawing.

(Figure 68) is clamped on the scale. This keeps the scale in use on the bottom and aids in speeding up the work.

Shop drawings are frequently made, allowing some integral part of one inch to represent one inch. The table on page 83 shows the proportionate size of the drawing for architectural and shop drawings. In the architectural scales, the proportionate sizes ¼, ⅛, 1/12, and 1/16 are the only ones usable for drawing shop models. On the shop scales, the additional scales, 3/32, 3/16, ⅜, ½ and ¾ sizes are made available. It is apparent from a close examination of the scale, that it was not designed for this use, but many draftsmen and teachers are using it. Examine any issue of Manual Training magazines and almost half of the drawings are labeled Scale 3/8″=1″ or 3/16″=1″, showing that this is common usage.

In figuring the spacing for two views of the library table shown in Figure 69, it is found that there are 72″ of drawing

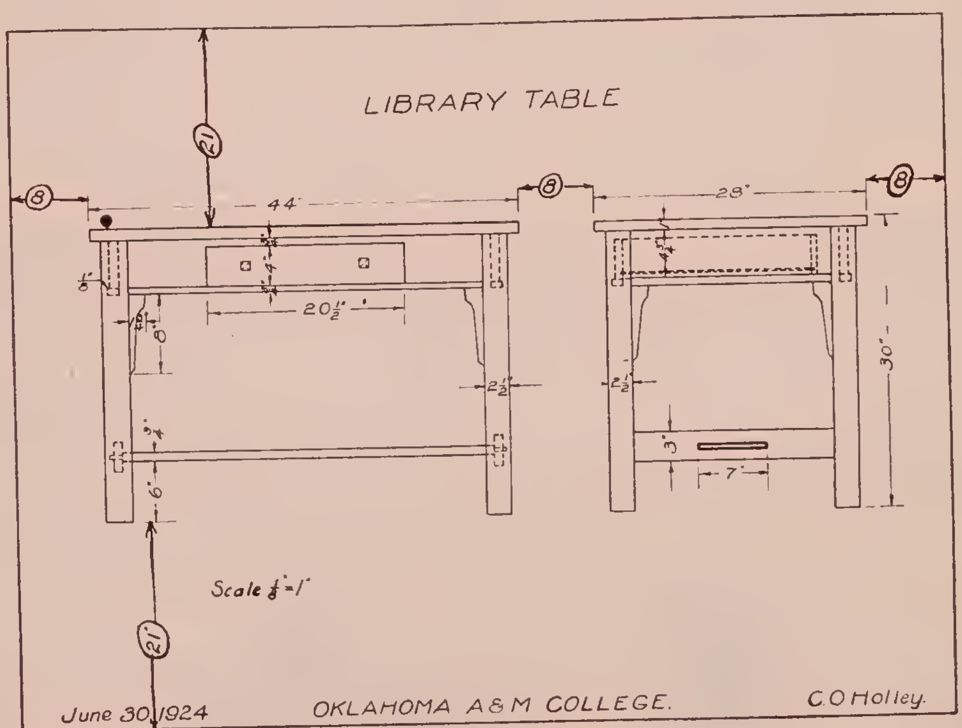


Fig. 69. Two views of a library table, drawn on 9x12 sheet to the scale ⅛″=1″.

lengthwise of the sheet. By referring to the table on this page under "Shop" the nearest sheet size is 72x96 using the scale 1/8″=1″. So in figuring the location of views we find the spacing as indicated in Figure 69. In making the drawing, always use the ⅛″=1″ scale for making all measurements.

Always designate the scale of a drawing unless it is made full size. It seems superfluous to write *scale full size* on the sheet, but some authorities recommend his. Always write out the full phrase, Scale ⅜″=1″ or Scale ¼″=1′; never say ⅜″ Scale or ¼″ Scale.

Table giving size of sheet and proportionate size for the ten different scales.

Scale	Architectural			Scale	Shop		
	Proportionate size of draw.	Size of 9x12 Sheet	Size of 10x14 Sheet		Proportionate size of draw.	Size of 9x12 Sheet	Size of 10x14 Sheet
3/32=1′	1/128	96x128′	80x112′	3/32″=1″	3/32	96″x128″	80″x112″
1/8=1′	1/96	72x96′		1/8″=1″	1/8	72″x96″	
3/16=1′	1/64	48x64′	40x56′	3/16″=1″	3/16	48″x64″	40″x56″
1/4=1′	1/48	36x48′		1/4″=1″	1/4	36″x48″	
3/8=1′	1/32	24x32′	20x28′	3/8″=1″	3/8	24″x32″	20″x28″
1/2=1′	1/24	18x24′		1/2″=1″	1/2	18″x24″	
3/4=1′	1/16	12x16′	10x14′	3/4″=1″	3/4	12″x16″	10″x14″
1″=1′	1/12	9x12′		1″=1″	Full size	9″x12″	
1½=1′	1/8	6x8′		1½″=1″	1½ size	6″x8″	
3=1′	1/4	3x4′		3″=1″	3 times full size	3″x4″	

Drawing No. 17. Make a scale drawing of some piece of furniture in the shop. A library or study table or the drawing table will be acceptable.

Drawing No. 18. Make a drawing of a built-in cupboard similar to the one shown in Figure 67. A kitchen cabinet from some standard mill works catalog will answer.

CHAPTER XVIII

Making Tracings

Tracings are made so that any number of additional blueprint copies of the drawing may be obtained. The making of blueprints from tracings permits the preservation of the orininal drawing or tracing. In case of competitive bids, all bidders work from identical drawings or prints.

There are two kinds of material used for making tracings. Tracing cloth is a very fine linen cloth fabric coated with a transparent starch material. This is very strong, and will stand rather hard usage and some erasures. It will not resist wrinkles when doubled, and it will show water spots if water should touch it. This material is very expensive, but is widely

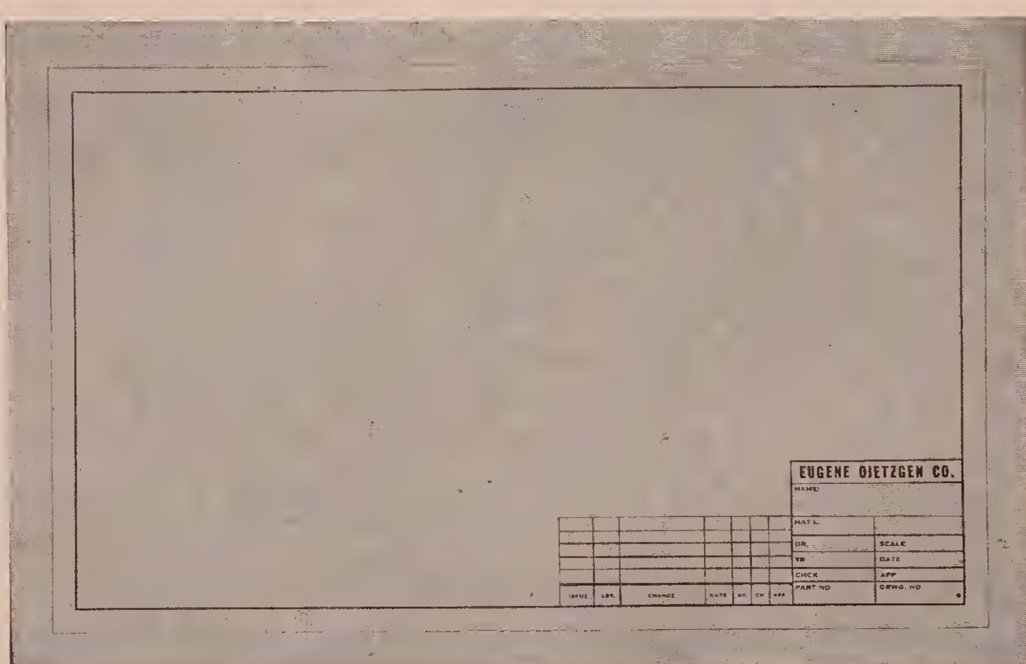


Fig 70. Tracing cloth or paper in sheet form. with border and title space printed on sheet.

used, especially where there is a possibility that many prints will be made from the copy.

The second material used is tracing paper. This comes in several varieties, white or cream, oiled or tissue, and heavy or light. It is in no way as strong or as permanent as tracing cloth, but it is relatively very much cheaper. It is entirely satisfactory when only a few prints are to be made. Architects use it very largely. Students when first attempting to make tracings should use tracing paper. After greater accuracy is attained, tracing cloth may be used.

Tracing cloth and paper usually have one glazed surface and one dull surface. There is some difference of opinion as to which side should be inked. The majority of authorities say that the unglazed side should be used when inking. Chalk dust or talcum powder is sometimes rubbed over the surface to cause the ink to adhere more easily. Extremely great care must be taken when making a tracing. No erasing should be permissible. Erasing will always injure the tracing cloth or paper.

Inking the original drawing is not necessary before making a tracing. In fact, this will be time wasted. If the drawing is to be traced, the pencil lines should be slightly heavier than they are usually made. Stretch the tracing paper or cloth over the drawing, using one tack at each corner. Finish the tracing before removing the work from the board if possible.

Draw in the outside or trim lines on the tracing with a soft pencil. The top and bottom guide lines for letters may be drawn with a soft pencil and thus aid in keeping the lettering in exact line. Soft pencil lines may be erased without seriously injuring the material.

Cleaning of tracing with sponge or other forms of cleaning erasers should be unnecessary. Follow the same order of inking when making the tracing as was given for inking the drawing. Tracing paper and cloth usually come in rolls of varying lengths and widths. Frequently, however, this ma-

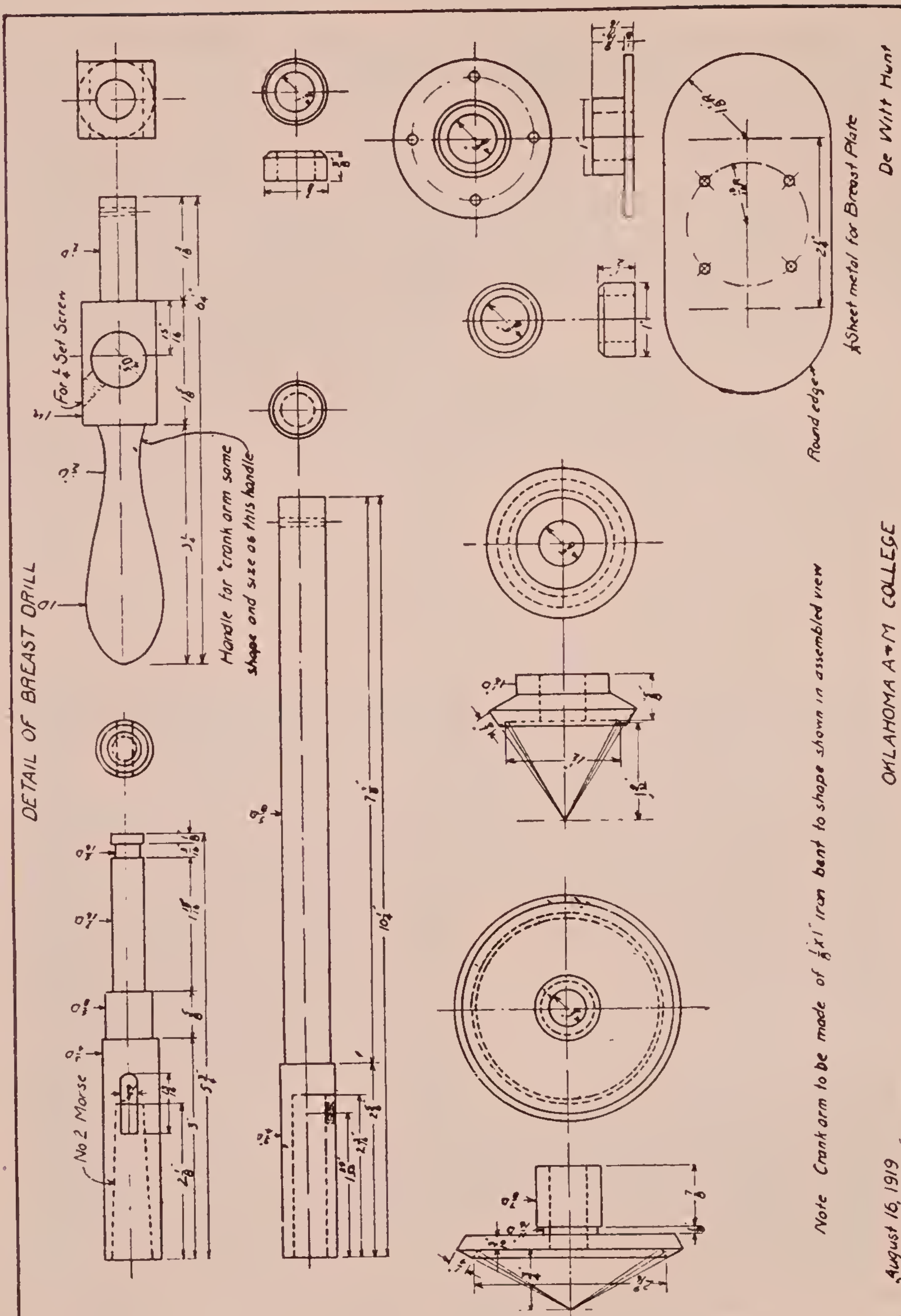


Fig. 71. A tracing showing detail of a Breast Drill.

terial may be obtained in sheets. Firms adopting standard sized sheets have the border and title space printed on the sheets. (See Figure 70.) One advantage in having standard sheet size is the ease of filing.

Drawing Problem. Make tracings of at least two of the last five drawings previously made.

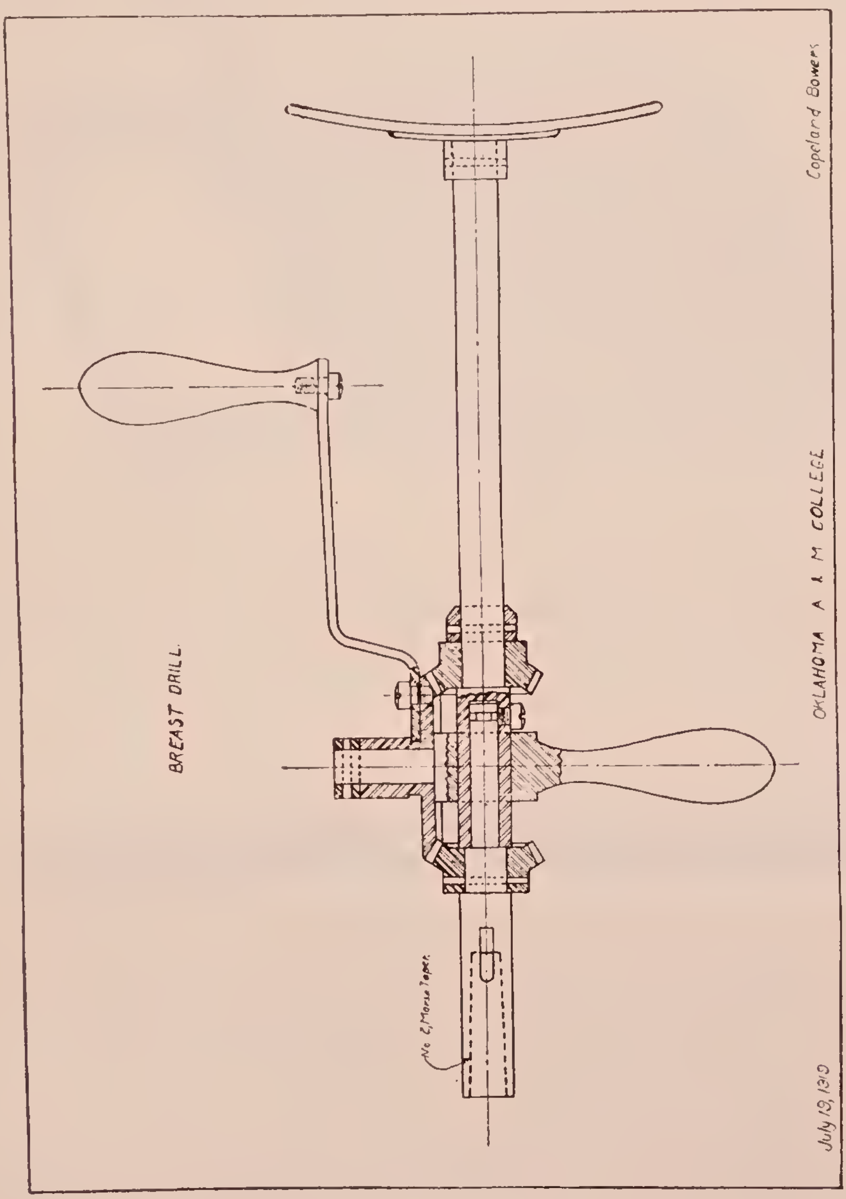


Fig. 72. A tracing of the assembly of a Breast Drill.

CHAPTER XIX

Making Blue Prints

Blueprints are made by exposing a sensitized paper, under a tracing, to the sunlight or to a strong artificial light for a definite time, then washing the print to fix the copy. The process is similar to that followed in printing a photograph from a negative. The tracing takes the place of the negative. The parts of the blueprint paper covered by the lines on the tracing wash out white, while all of the background or the parts affected by the sun become a deep blue color.

Blueprint paper comes in rolls, 24, 30, 36, 40, etc. inches in width. It is carefully wrapped in light proof coverings. It must be kept away from the light, and deteriorates rapidly. A test for blueprint paper may be made as follows: tear off a small piece of paper from the new roll; wash it in clear water. It should wash out a clear white. Expose a small piece of paper to the sun for 30 to 45 seconds. Wash this, and it should become a deep blue. Blueprint paper should be kept in a tin or pasteboard tube when not in use. The wide roll may be sawed into rolls of convenient widths with a handsaw. For the 9x12 sheets, buy a 32″ roll and saw it into thirds.

Fig. 73. A tube in which the blueprint roll may be kept.

When making a blueprint, take the back out of the printing frame. Clean the glass thoroughly, being sure that it is dry. Place the tracing on the glass with the inked side next to the glass. Over this spread the blueprint paper with the sensitized side next to the tracing. Then lay the felt pad over the blueprint paper and insert the back pieces. Expose

the frame to the direct rays of the sun. These rays should strike the glass perpendicularly. Do not attempt to hold the frame inside glass windows or screwed windows. Time the exposure carefully, using a watch with a second hand and giving the print about 30 seconds. Remove one end-piece and

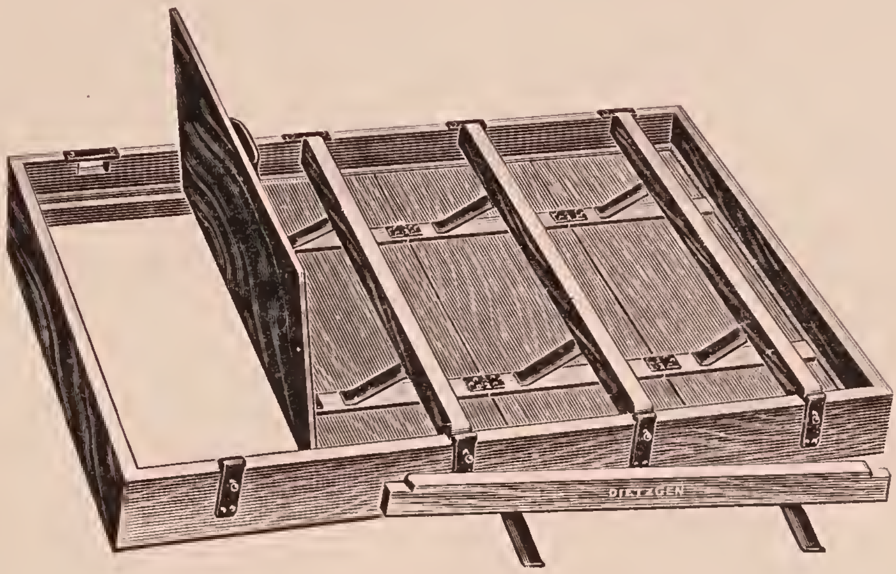


Fig. 74. A well-designed printing frame.

examine print. The lines will appear dully. Give the print a few seconds more exposure, then remove the blueprint paper and wash quickly in a bath of pure, clean water. Allow print to stand in the water for a few minutes; then hang on a line to dry. Be sure to dry the print inside, not in the sun. Do not allow any water to splash on the printing frame or tracing.

Blueprint paper is now made so that no chemical is needed in the bath. For many years, certain chemicals or fixers have been added to the bath water when washing the blueprint. This may be done now, but it is not necessary.

A box may be made to hold the blueprint roll so it may be pulled out and torn off in a lighted room.

Large printing frames to roll out of a window on tracks are used in some drawing rooms. Automatic electric printers and washers are available for the blueprinting concern or the big plant.

Assignments: Make a blueprint from one of the tracings made under instructions contained in Chapter XVIII.

CHAPTER XX

THE 10 x 14 STANDARD SHEET

All of the drawing problems following this chapter are to be drawn on a new sheet size. The sheet used so far was 9x12, with a half inch border and a minimum of lettering. The new sheet has 10″x14″ drawing space, 1″ at bottom for lettering, 1″ at left for border, and ½″ border at top, bottom, and right. This sheet was inspired by a drawing appearing in a recent number of the "House and Garden" Magazine. The drawing is reproduced in Figure 75.

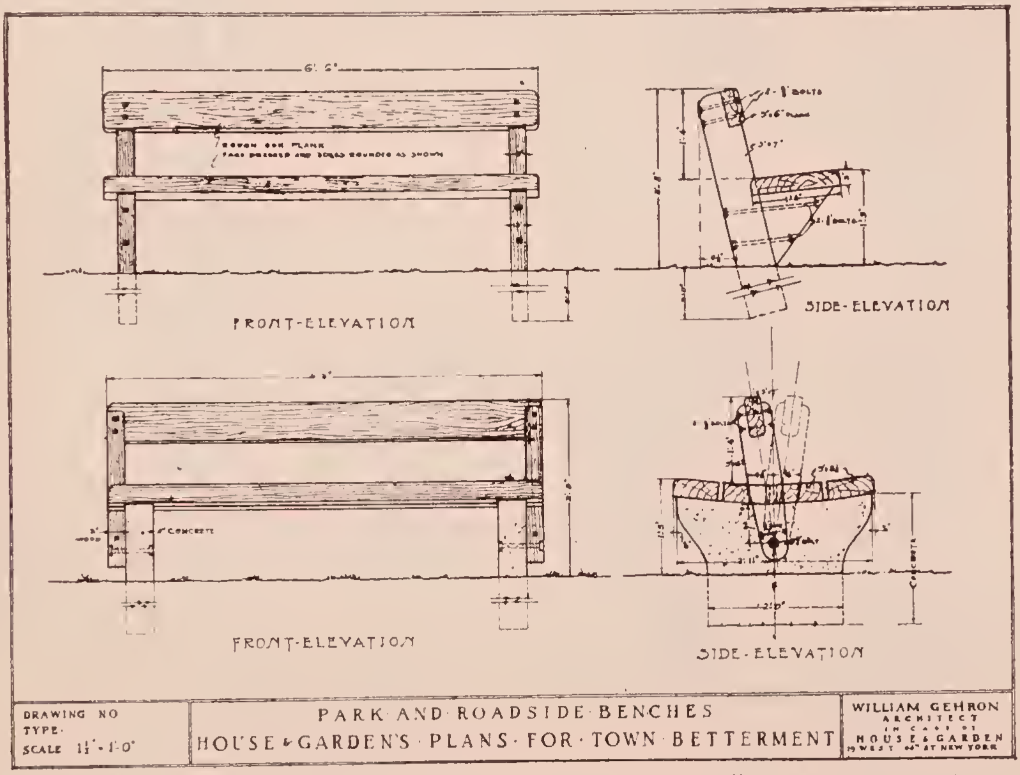


Fig. 75. A drawing from "The House and Garden" magazine which suggested the standard sheet form used in this text.

Detailed dimensions of this sheet are found in Plate XVI, which gives a letter sheet designed for this size of sheet.

Note that all lettering in the center space at the bottom is upper case, and that all lettering in the two end spaces is lower case.

Note: Assignments given hereafter, require a complete and finished drawing, fully inked, and every third sheet must be dimensioned.

Assignment: Lay out four sheets of the new size; letter them completely, except for name of drawing. Drawing No. 19. On the first sheet make a new letter sheet exactly as laid out in Plate XVI.

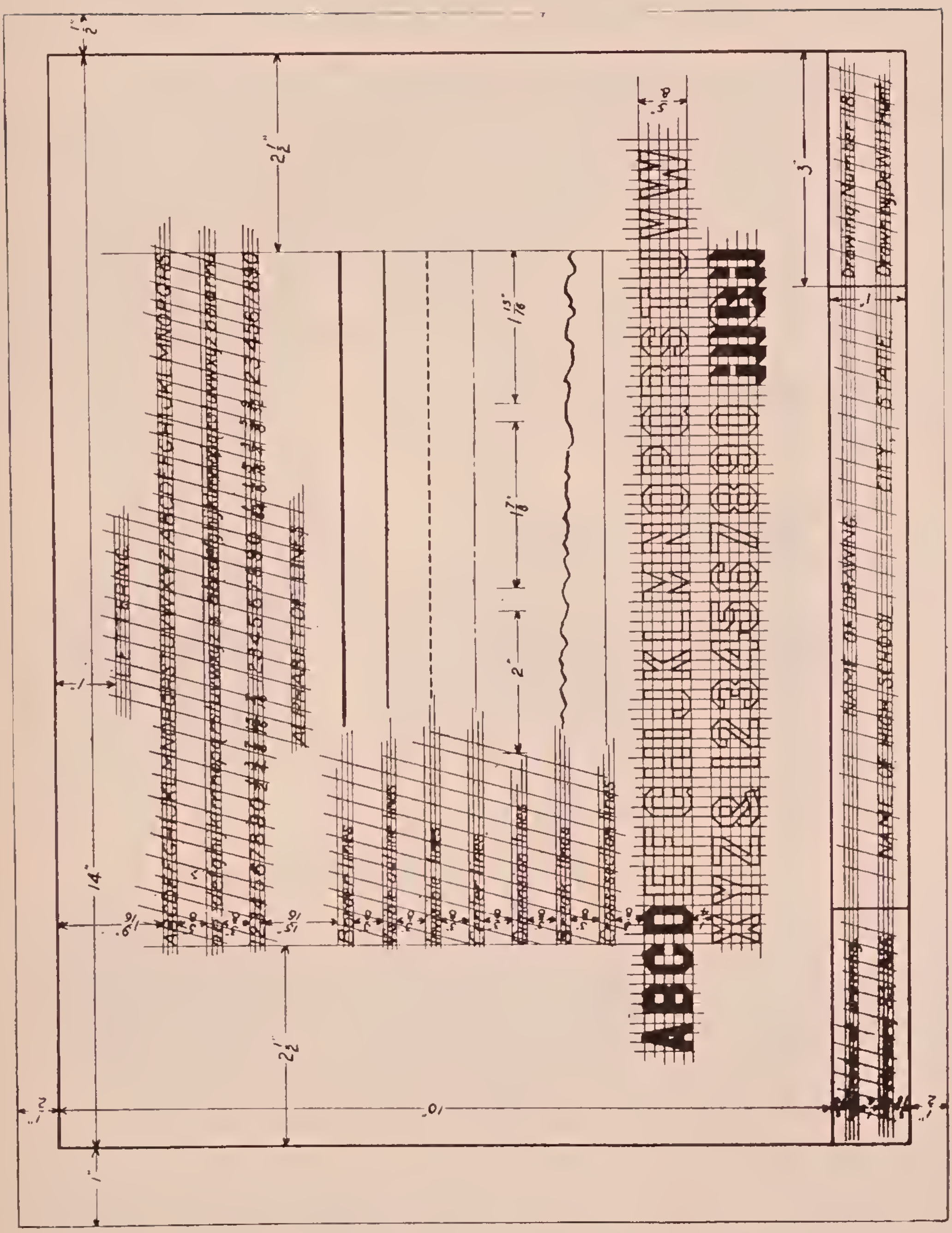


Plate XVI. The 10x14 standard sheet.

CHAPTER XXI

Sectional Views in Mechanical Drawings

When the inner details of an object cannot be clearly shown by representing the hidden or invisible lines with dotted lines, a part of the object is imagined as cut away to expose the inner details. This is called making a *sectional view.* The *full section,* showing an object cut in halves with all of the inside lines becoming visible is exemplified in Figure 76.

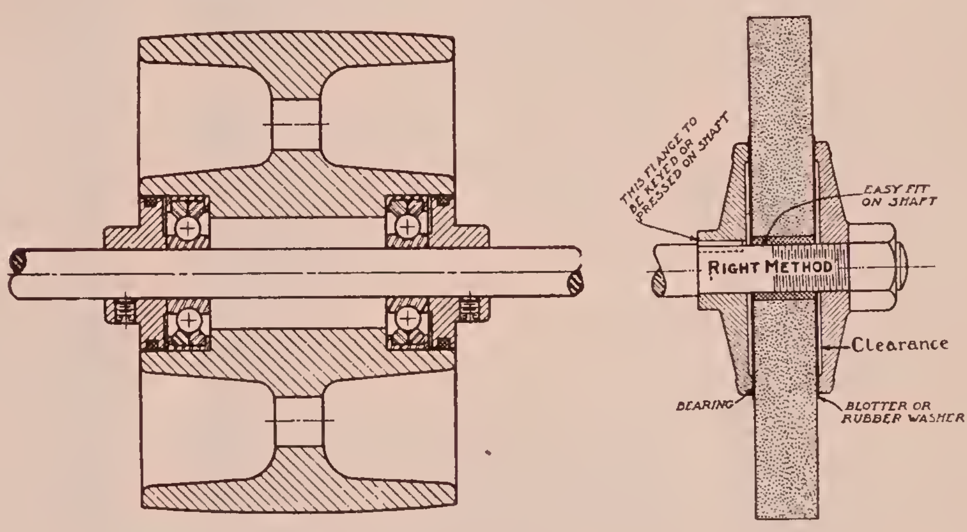


Fig. 76. Full sectional views of a ball-bearing loose pulley and an emery wheel.

When an object is cut entirely through the center, the resultant drawing is called a full sectional view. The sectioning of objects is usually accomplished by passing a plane through the center-line. Actual problems showing sectional views are often made for the drawing room by sawing a model into two equal parts with a hack saw. Cross section lines are used to represent the surfaces sawed apart, and they actually may represent the saw marks. The following general rules govern making sectional views:

1. The shaft in the center is not cut, and is therefore not cross-hatched. (Figure 76)

2. Do not draw any invisible lines behind sectional views. Only details in the plane of intersection are represented in this view.

3. Usually only one view is sectional. (Figures 78 and 79) In any case, the other view does not show the detail of sectioning.

4. Cross-hatch lines to represent different metals are made in different ways. (Figure 77)

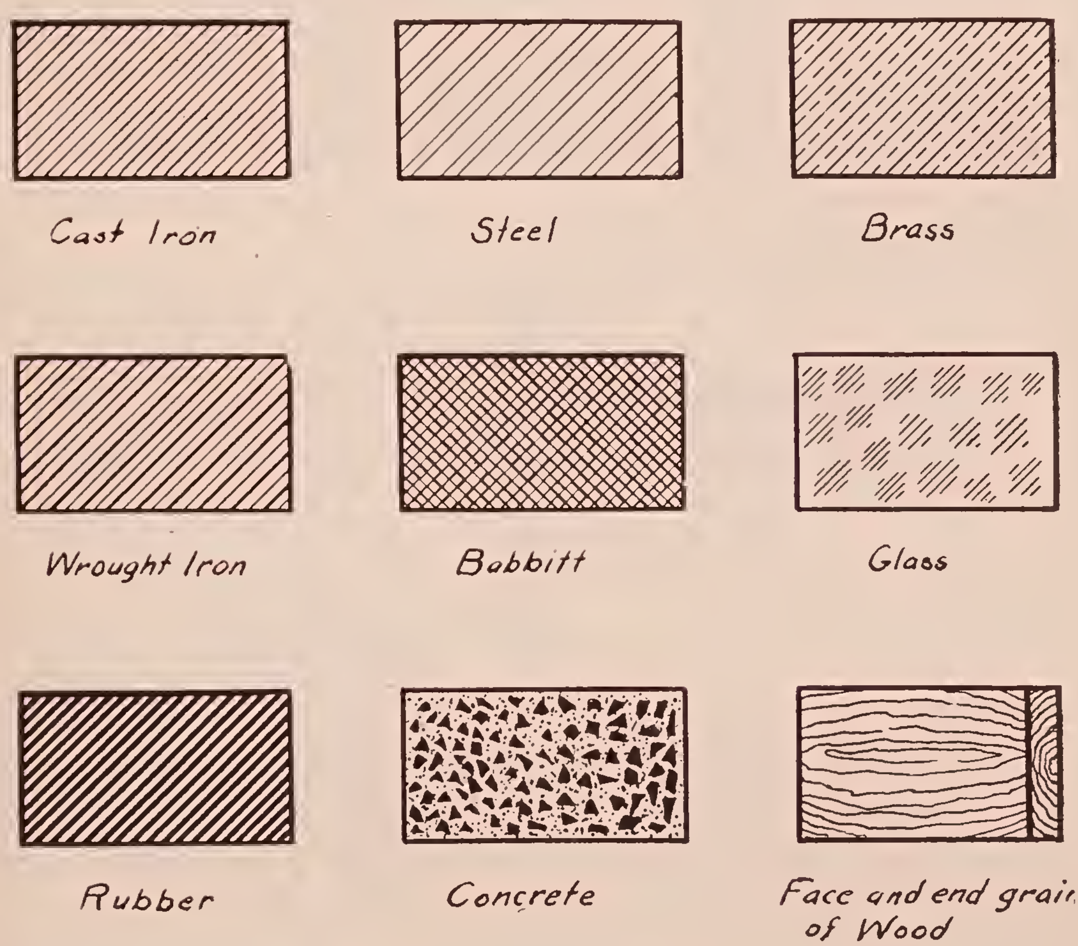


Fig. 77. Standard cross-hatch lines for nine common metals and materials.

5. Almost all cross-hatch lines are made at 45° to the horizontal. Some draftsmen make the lines representing steel 60° to horizontal.

6. Cross-hatch lines run at opposite angles in adjacent parts.

7. Cross-hatch lines run the same direction in all places representing the same part.

When one-fourth of an object is cut away, exposing one-half of it for a sectional view, it is called a half-sectional view. This is used where the object is symmetrical and the full-sectional view would show no additional detail. The purpose of the half-sectional view is twofold; first, to save the time required to draw and ink the detail required in the full-sectional view; second, to show in half of the drawing all of the lines representing the outside of the object and at the same time all of the inner details in the other or sectioned half of the drawing.

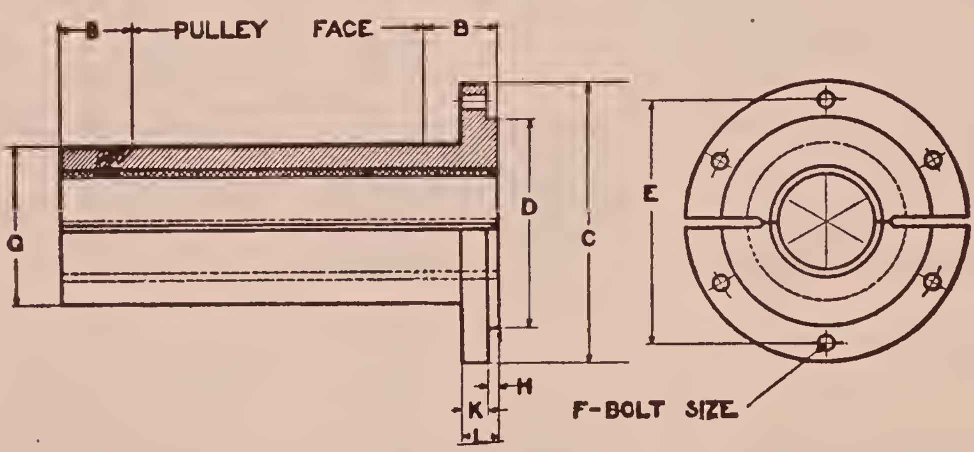


Fig. 78. A half-sectional drawing of a babbitted sleeve for a clutch.

In Figure 78 is shown a half-sectional view of a babbitted sleeve for a clutch. Each sleeve has a 5/16" shell of babbitt in it. The sizes of three of these clutches are given in the following table:

Dimensions

For all clutches	B	C	D	E	F	H	K	Pulley Face	G	Shaft Size
10" to 14" inclusive	2½	8½	6	7	½	¼	1	6"	4½	2½
16" to 24" inclusive	3	11½	8 $\frac{9}{16}$	10	⅝	$\frac{7}{16}$	1 $\frac{1}{16}$	6"	5	3
28" to 30" inclusive	3½	13½	9	11½	¾	½	1¼	6"	5½	3½

When only a part of an object is cut away to show an inner detail, the drawing is called a partial-section. Frequent-

ly an object is symmetrical about an axis and also of the same size and material throughout its length. In this case much time and work can be saved by half-sectioning a part of the length. In Figure 79, the object is clearly shown by the

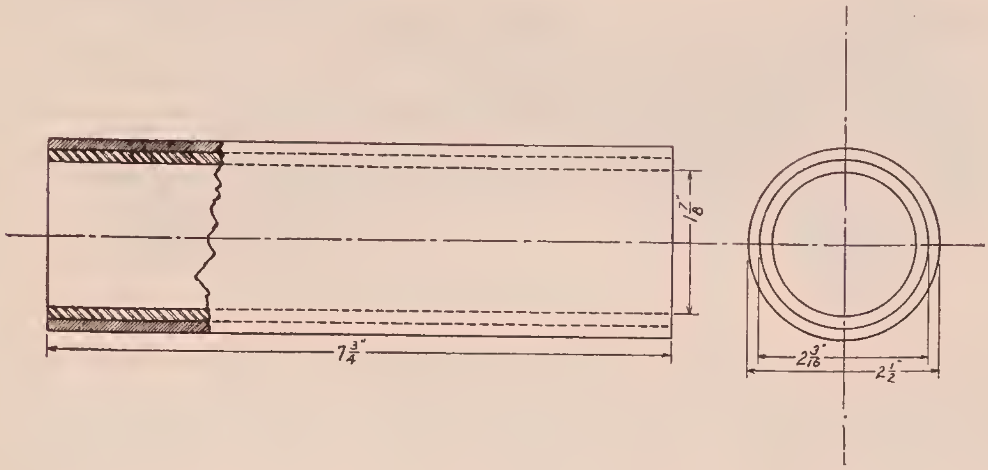


Fig. 79. A partial section of a babbitt-lined sleeve.

partial section at left of front view. Partial sections may be used at any place in a drawing, or even in several places in the same drawing. Figure 80 shows four partial sections in the same drawing.

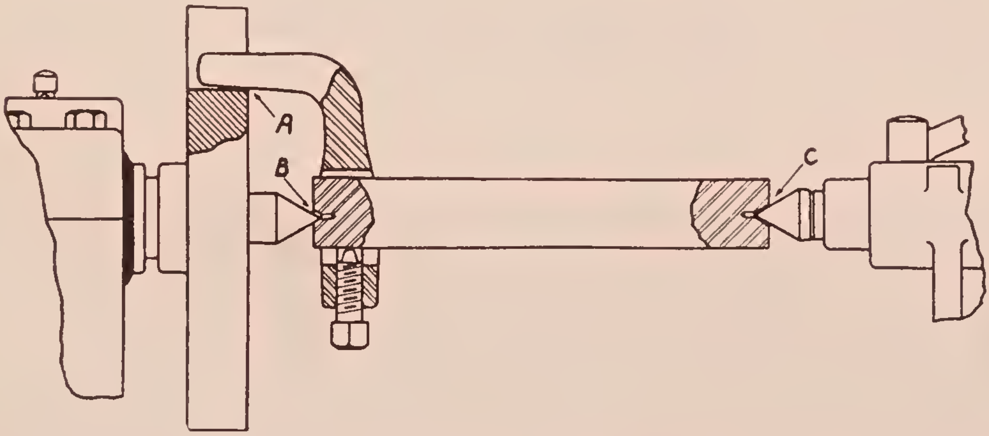


Fig. 80. Using partial sections of parts in an assembly drawing. From the South Bend Lathe Book.

Cross hatching lines are usually drawn without mechanical aid for spacing them. For ordinary work, this is the usual

way, but in special work on show drawings, a section liner is used. Figure 81 shows a rather practical form of mechanical spacer for drawing cross-section l'nes.

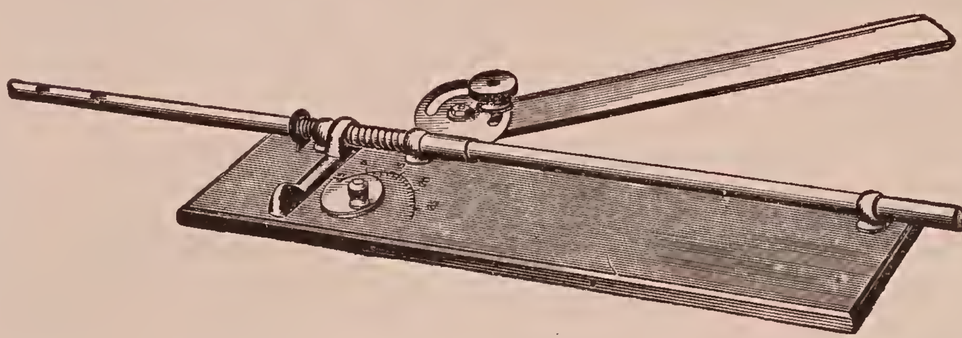


Fig. 81. A cross-section liner.

Drawing No. 20. Draw top and front views and make full section front view of any size lever end given in Figure 82, using the table of sizes given below:

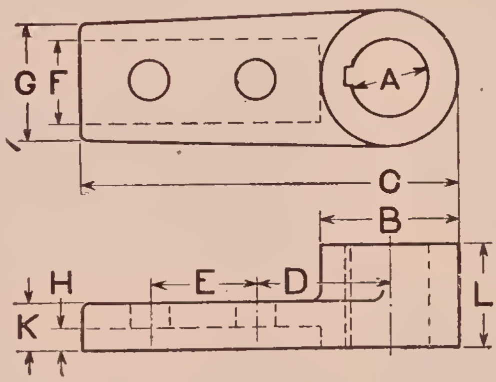


Fig. 82. A standard lever end.

Table of Sizes of Lever End

A	B	C	D	E	F	H	K	L	M	Bolts
$1\frac{7}{16}$	3	$9\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{9}{16}$	$\frac{1}{2}$	1	3	$1\frac{1}{4}$	$\frac{5}{8}$
$1\frac{15}{16}$	$3\frac{5}{8}$	$10\frac{1}{2}$	$3\frac{3}{4}$	3	$3\frac{1}{16}$	$\frac{1}{4}$	1	4	$1\frac{1}{2}$	$\frac{5}{8}$
$2\frac{3}{16}$	4	$8\frac{3}{4}$	$3\frac{1}{2}$	2	$2\frac{9}{16}$	$\frac{3}{8}$	$\frac{7}{8}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{5}{8}$
$2\frac{7}{16}$	5	10	$3\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{9}{16}$	$\frac{5}{8}$	$1\frac{1}{4}$	3	$1\frac{1}{4}$	$\frac{5}{8}$
$2\frac{15}{16}$	$5\frac{1}{2}$	11	$4\frac{1}{2}$	$2\frac{1}{4}$	$3\frac{1}{16}$	$\frac{1}{2}$	$1\frac{1}{8}$	3	$1\frac{3}{4}$	$\frac{3}{4}$

Drawing No. 21. Make half section front view of flanged bearing described in Figure 83. This bearing has a lining of $\frac{1}{4}''$ of babbitt next to the shaft. Use the dimensions given in the table below and in the larger sizes, draw a half circle for right end view.

Table of Sizes of Flanged Bearing.

Shaft Sizes	A	B	T	D	E	F	O	Bolts
$1\frac{11}{16}$	$5\frac{1}{4}$	$3\frac{3}{4}$	$\frac{5}{8}$	$2\frac{7}{8}$	$5\frac{7}{8}$	$\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{1}{2}$
$1\frac{15}{16}$	6	$4\frac{1}{4}$	$\frac{11}{16}$	$3\frac{1}{4}$	$6\frac{1}{2}$	$\frac{1}{4}$	5	$4\frac{1}{2}$
$2\frac{3}{16}$	$6\frac{3}{4}$	$4\frac{3}{4}$	$\frac{3}{4}$	$3\frac{5}{8}$	$7\frac{1}{8}$	$\frac{3}{8}$	$5\frac{1}{2}$	$4\frac{1}{2}$

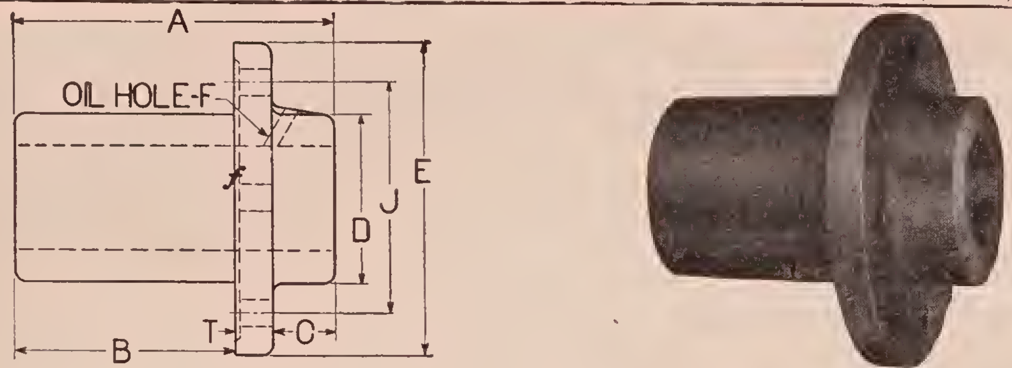


Fig. 83. Flanged bearing—babbitted.

Drawing No. 22. Make a full section of the Economy center point for lathe tail stock shown in Figure 84. The removable point is high speed steel; the other parts are mild steel. Draw front and right views.

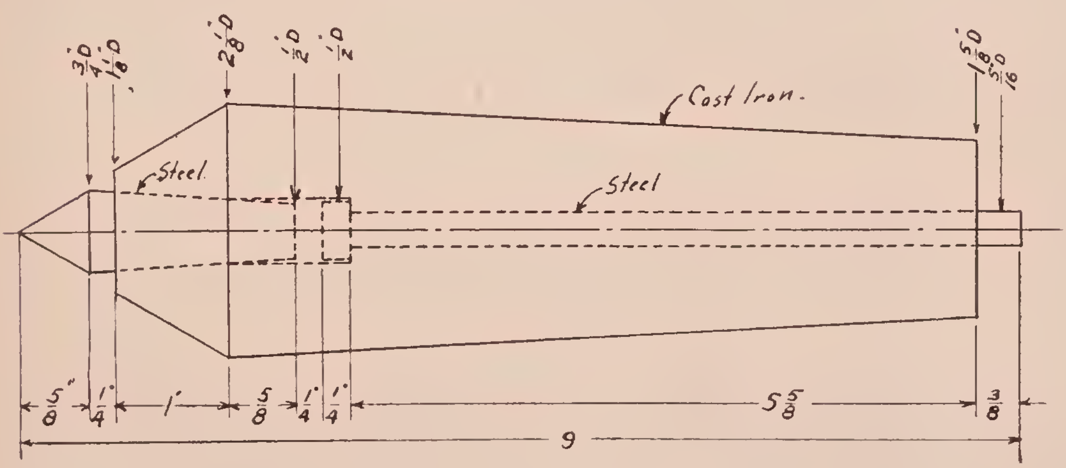


Fig. 84. The economy center point.

Drawing No. 22a. Make a two-view drawing of one of the babbitted sleeves in Figure 78.

CHAPTER XXII

Tangent Problems

Tangent problems are very common in mechanical drawing. The ability to recognize them and to understand the geometry governing them will aid greatly the draftsman who hopes to progress satisfactorily. The experienced draftsman may locate centers of circles and points of tangency by guess, but he understands quite well where these are and aided by a clear conception of final appearances, he can guess to an acceptable degree of accuracy. But the beginner, in representing a rounded corner, might miss the required quarter circle by as much as ten degrees.

The general consideration of tangents has been divided into five groups based on five common tangent problems. These five cases of tangents are similar to as many theorems in geometry. At least two drawings should be made involving each of these cases of tangents and in each advanced problem, the cases already covered will possibly be included.

Five Cases of Tangents.

Case I. When a circle is tangent to two perpendicular lines.
Case II. When a circle is tangent to two parallel lines.
Case III. When a circle is tangent to two divergent lines.
Case IV. When a circle is tangent to a line and a circle.
Case V. When a circle is tangent to two other circles.

Two general problems are always necessarily considered in these tangent cases. First, having given the lines to which the circle is tangent, the center of the tangent circle must be located. Second, after the tangent circle is drawn, the points of tangency must be located. These problems involve a very delightful application of the geometry of the locus of points.

CHAPTER XXIII

Tangent Problems Case I

When a circle is tangent to two perpendicular lines. Many manufactured articles are improved in appearance and usefulness by being made with rounded corners. This is particularly true of corners of castings. Fillets in castings, or inside round corners are also typical of this case of tangents.

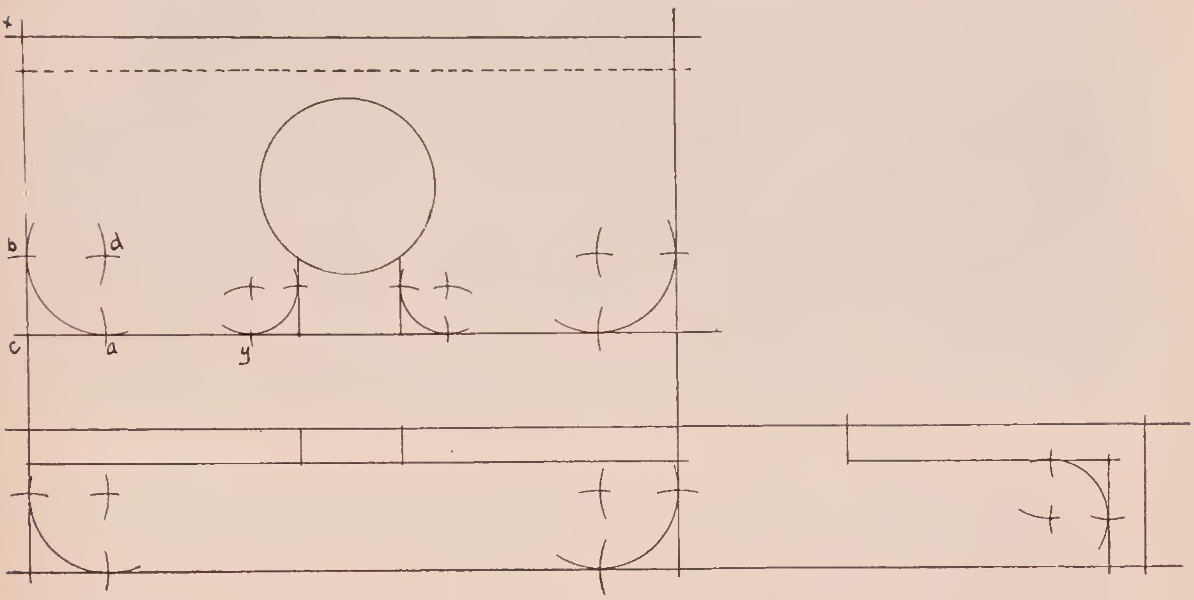


Fig. 85. Three views of a cast iron tool rack showing use of rounded corners and fillets

The cast iron tool rack shown in Figure 85 is a good example of the common use of rounded corners. This drawing shows the pencil drawing of the three views of the tool rack. After the three views are blocked out, the circle is drawn in the top view and the throat is drawn and projected to the front view, we have the problem of drawing the tangents.

The center of the tangent circle is located as follows:

Set compass at desired radius. With corner as a center "c", (Figure 85) draw short arcs on the two lines, a and b;

with a and b as centers draw two arcs intersecting at "d". This will be the center of a circle tangent to the two perpendicular lines. Other methods may be used providing always that the solution may be proved by geometry.

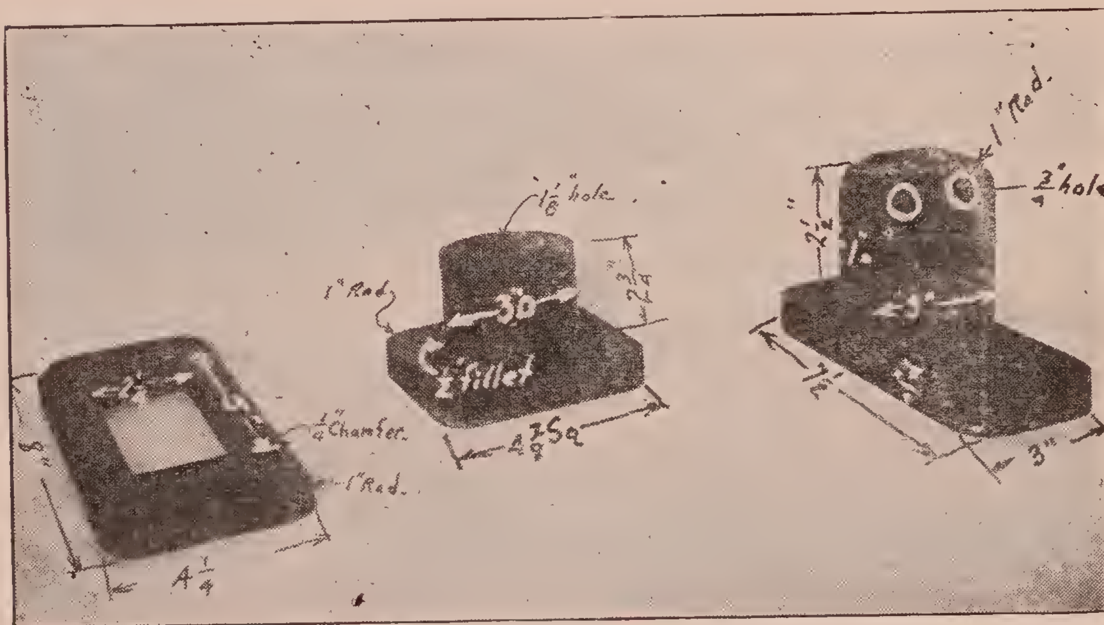


Fig 86. Photograph of easy tangent problem.

The points of tangency will be at the intersections of the first arcs and the two perpendicular lines, or at a and b. In inking the drawing, the points of tangency are of great help. Ink all circles and arcs of circles first. Thus the quarter circle a-b will be inked. Then, after arcs of circles, all straight lines are inked. The line b-x is inked from the point of tangency b to the corner x. The line a-y is inked later, from the point of tangency, a, or the end of the quarter circle to the point of tangency, y. Good joints must be made when inking. The ruling pen must be set to draw a line of exactly the same thickness as the inking compass draws.

Be sure to follow the order of inking as suggested above, and as was given in Chapter XIV for all tangent drawings.

Drawing No. 22. Draw three views of any problem given in figures 86 or 87.

Drawing No. 23. Draw two or three views of any one of the problems given in Plate XVII.

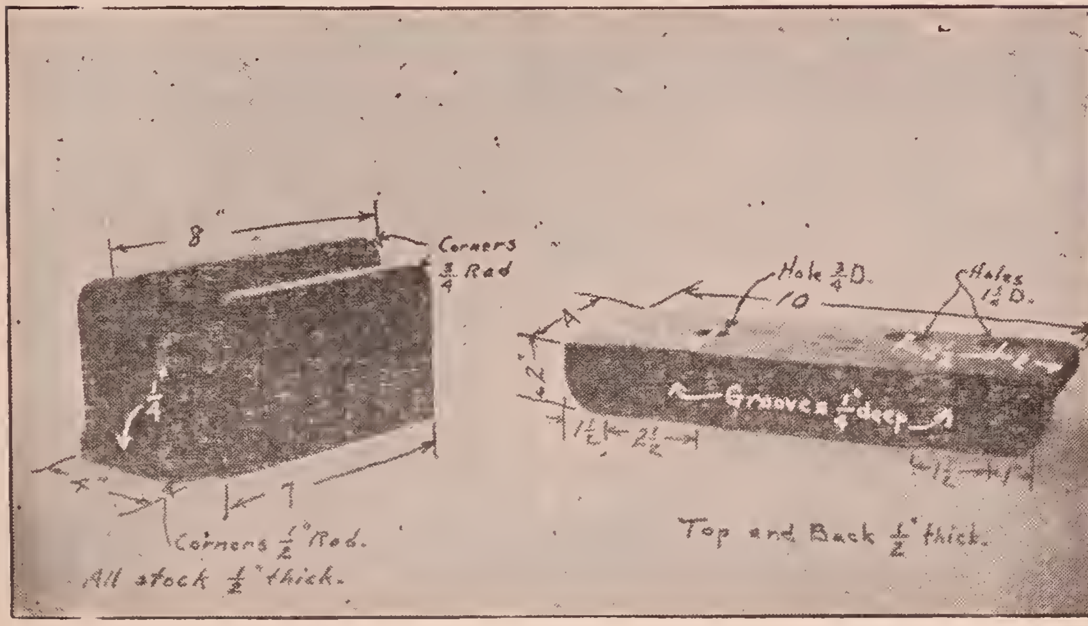


FIG. 87. Photograph of easy tangent problem.

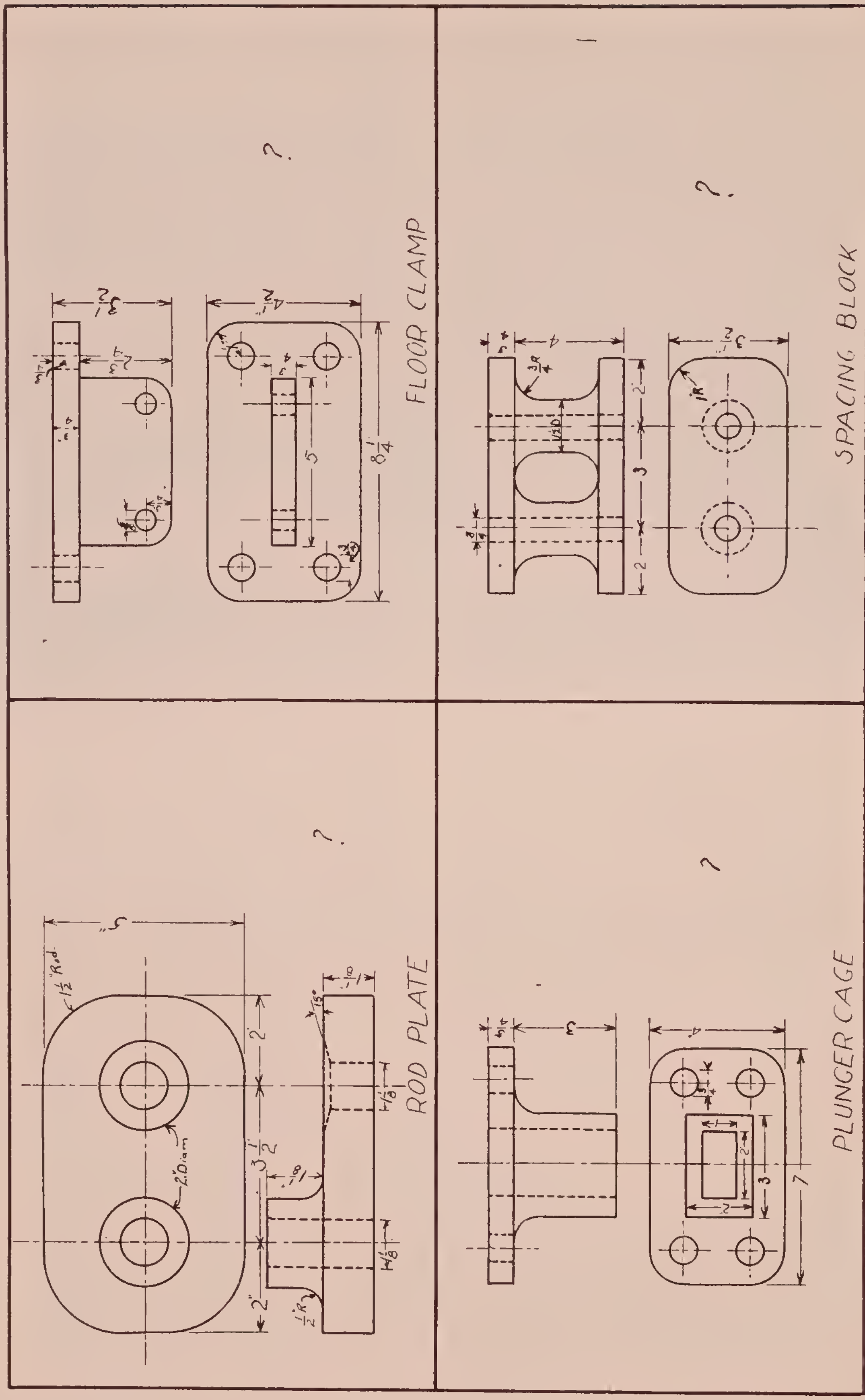


Plate XVII. Tangent Problem Casé I.

CHAPTER XXIV

Tangent Problems, Case II

When a circle is tangent to two parallel lines. Rounded ends of castings, slots with rounded ends, and chain links are typical of this case of tangents. This problem occurs very frequently in machine drawing.

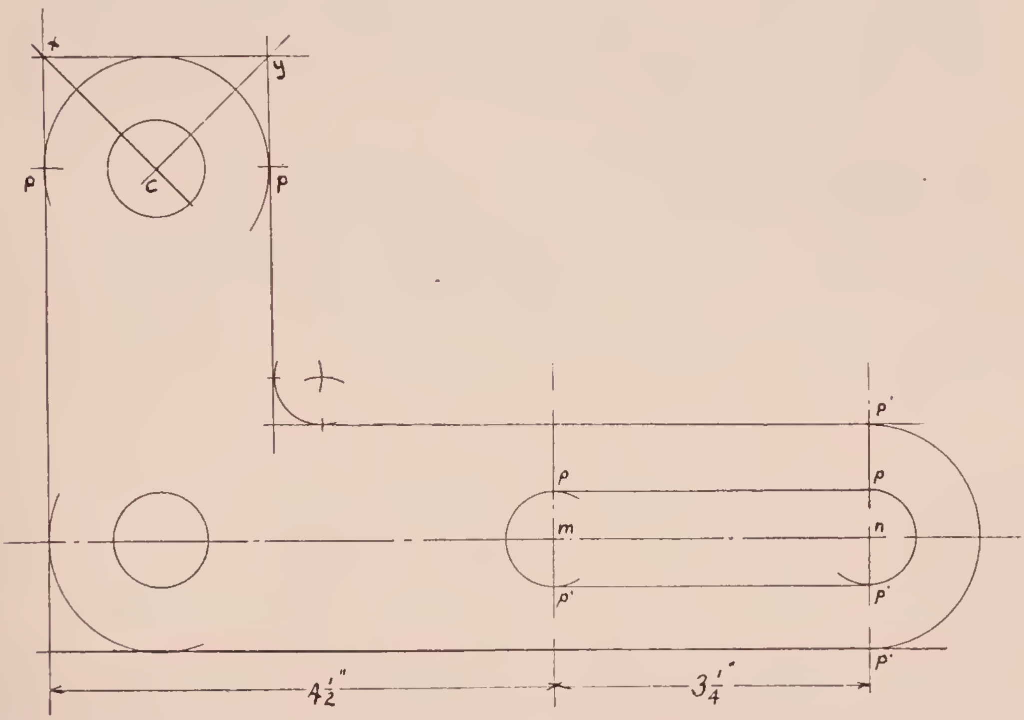


Fig. 88. The front view of a rocker arm showing examples of Case II of tangents.

The front view of a rocker arm in Figure 88, shows typical examples of Case II of tangent problems. There are two possibilities for beginning the problem. In the vertical arm drawing, it is assumed that the three outline lines are drawn; the horizontal arm represents the example of when center lines locate the centers of circles.

When outlining lines are already drawn, the center of the circle tangent to the three lines is located by drawing the two

45° lines from the corners; x-c and y-c in Figure 88. The intersection of these two lines locates the center of the tangent circle.

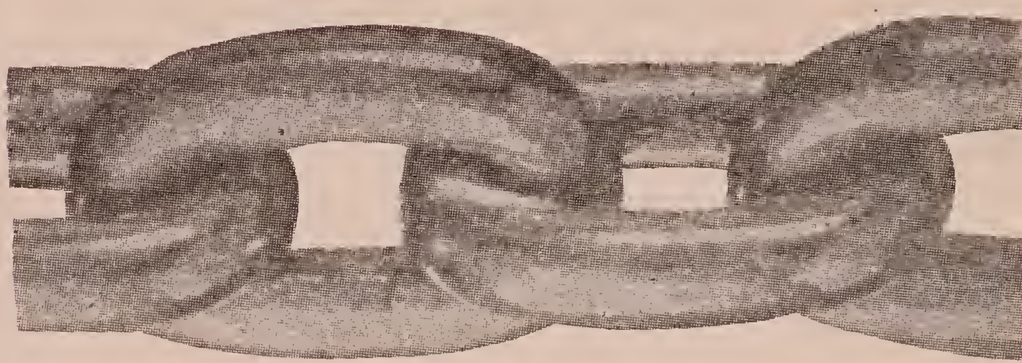


Fig. 89. Chain links form Case II of tangents.

The points of tangency are located by drawing a diameter perpendicular to the two parallel lines. The line p-p in Figure 88 locates the two points of tangency. These points of tangency locate the exact places where the circle stops and lines begin.

When center lines locate the centers of the half circles, draw the circles first and then draw the lines tangent to the edge of the circles. The center lines through points m and n, Figure 88, locate the centers of the circles. Draw a little more than half of the circumference of the circles with the

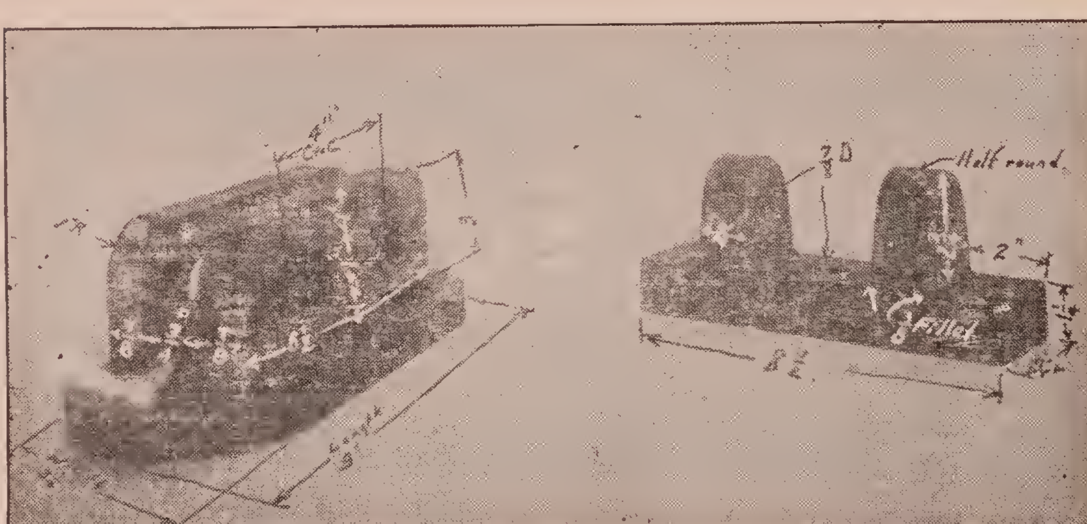


Fig. 90. Tangent problems Case II.

pencil compass; then draw the horizontal lines tangent to these circles.

Center lines locating centers of circles, when extended, locate points of tangency. The six points p′ are the points of tangency as located by the center lines, extended. When inking the drawing, ink all half circles first, then ink straight lines joining them.

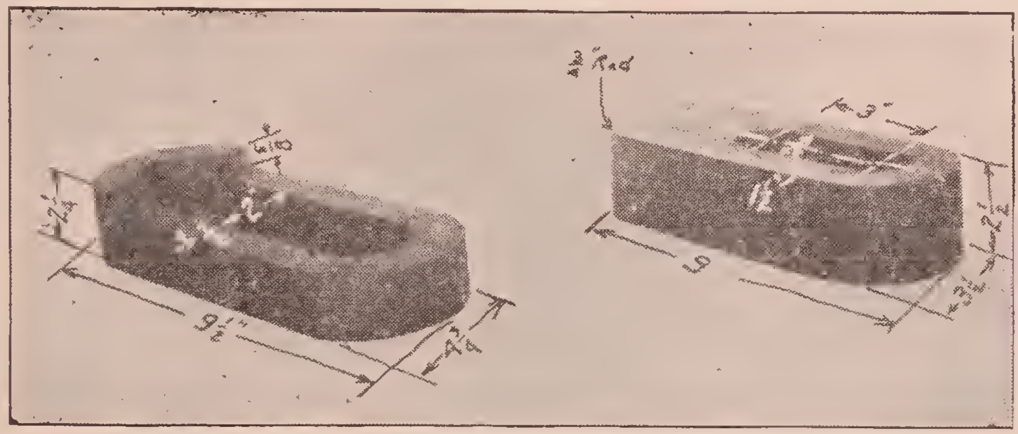


Fig. 90a. Tangent Problem Case II.

Drawing No. 24. Draw three views of two adjacent links of a chain. Each link made of ¾″ round iron, link 5″ long, 3″ wide. (See Figure 89.)

Drawing problem No. 25. Draw two views of one of the problems in Figure 90, Figure 90a or Figure 91.

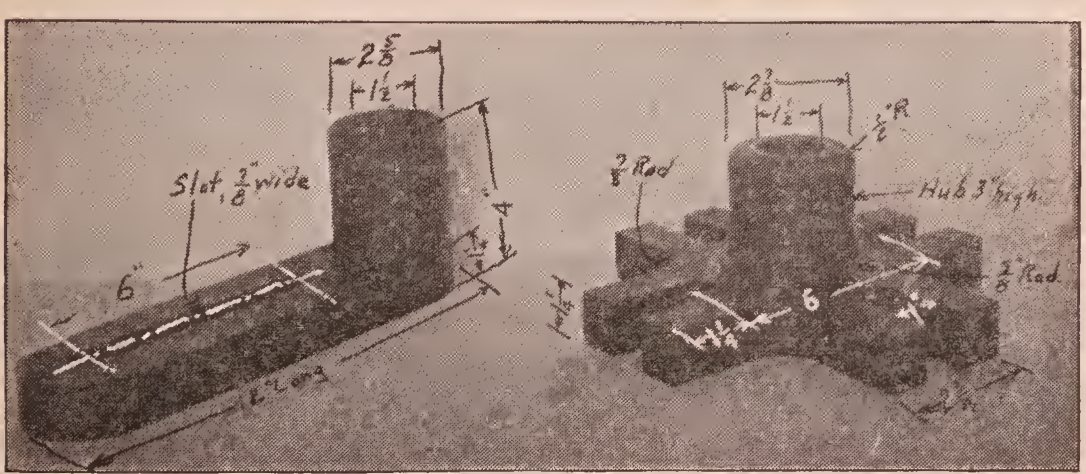


Fig. 91. Tangent problems Case II.

CHAPTER XXV

Tangent Problems, Case III

When a circle is tangent to two divergent lines. The packing gland is an excellent example of this tangent problem. Figure 92 shows two views of a packing gland. In the front view, the problem of a circle tangent to two divergent lines

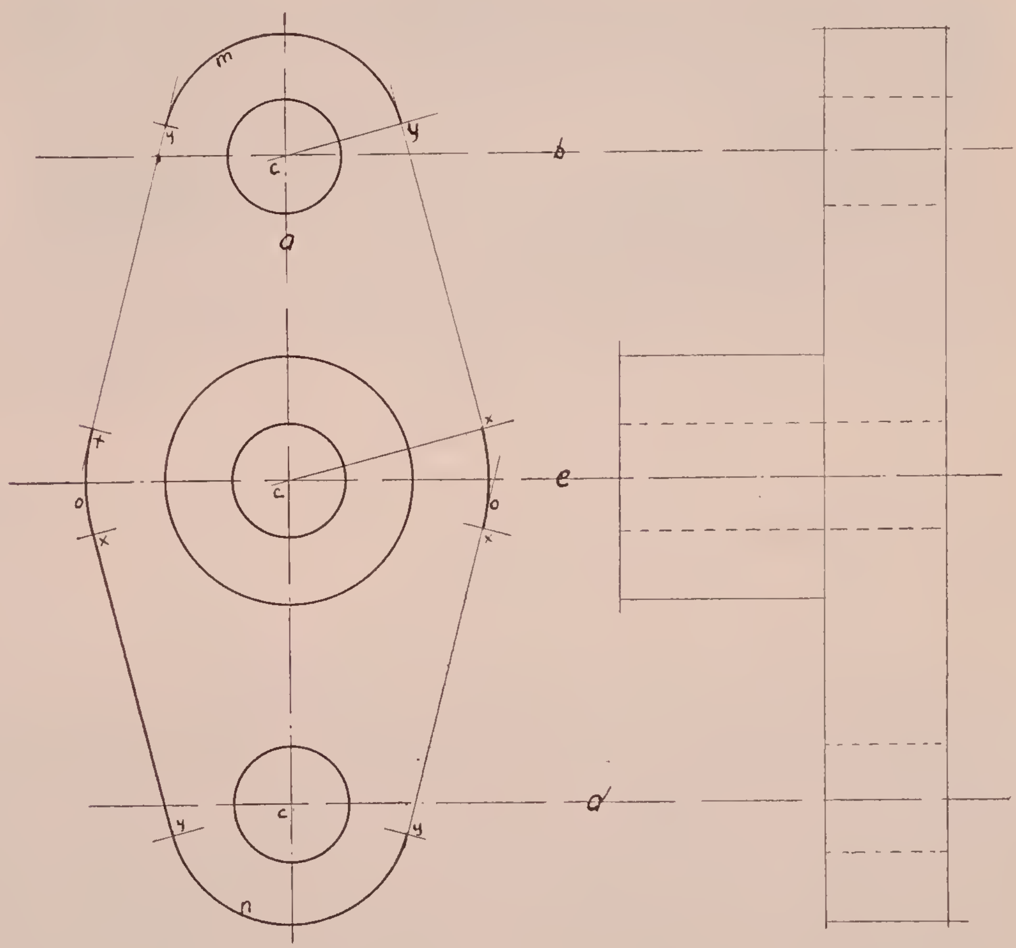


Fig. 92. A packing gland, showing all of the circles and one line already inked.

is well illustrated. There are two divisions of this problem. First, when the circles are already drawn and the straight lines are drawn tangent to the two circles; second, when the

lines are given and the circle of given radius must be drawn tangent to both of them.

In Figure 92, the center lines a, b, d and e are first located and drawn. Then all of the circles with centers at c, c, and c, are drawn. The circles o, m, and n, should be drawn in their entirety. The four tangent lines, x-y are then drawn, just touching the circles. The problem now is to locate the points of tangency at x and y.

The point where a line is tangent to a circle may be located by drawing a line through the center of the circle, perpendicular to the tangent line. To locate the points of tangency x or y in Figure 92, it is only necessary to draw a line c-x or c-y, through the center c, perpendicular to the line x-y.

To draw a line perpendicular to a given line, set the hypothenuse of either triangle on any straightedge with either leg coinciding with the given line; slide the triangle along the straightedge until the other leg intersects the line at the proper point. This *trick of the trade* is well worth knowing. Refer to Figure 93 for a graphic representation of this rule. The given line A-B is at an odd angle to the horizontal. The 45° triangle is placed with the hypothenuse on the tee square so that one leg coincides with the line. The triangle is moved

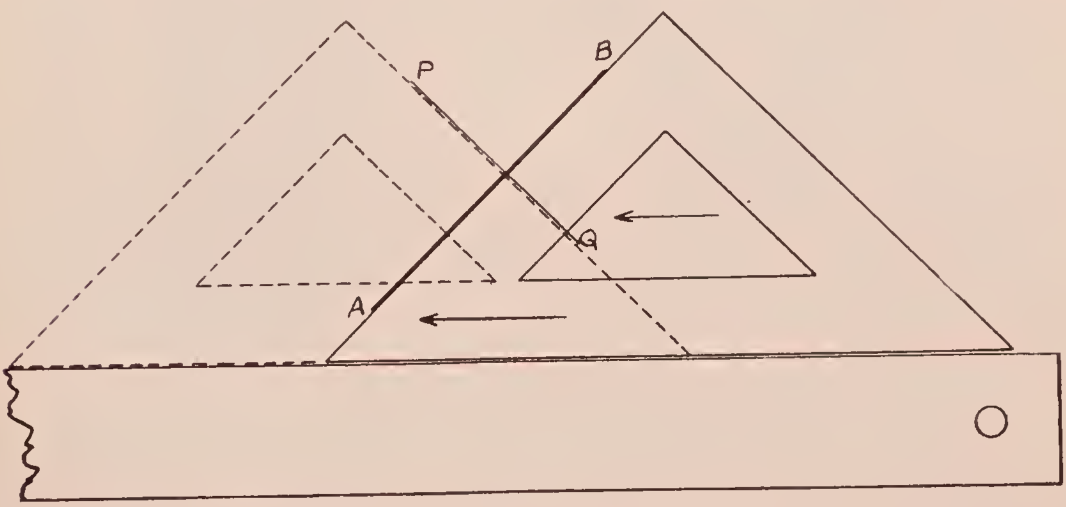


Fig. 93. To draw a line perpendicular to a given oblique line. to A-B.

along the tee square until the other leg coincides with the point P. The line P. Q. is then drawn perpendicular to A-B.

Thus, the points of tangency x and y are located and the circles are inked only to these points. The straight lines joining these arcs of circles are then inked.

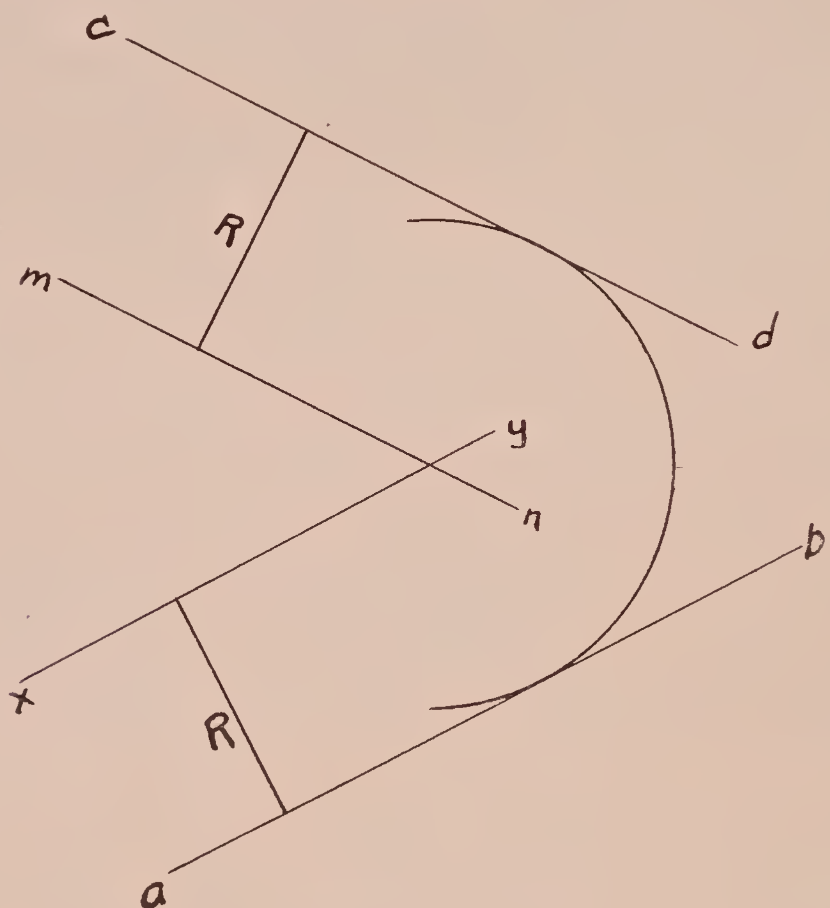


Fig. 94. Locating the center of a circle tangent to two given divergent lines.

When two divergent lines are given, (See Figure 94), the center of the circle tangent to them both is solved as follows:

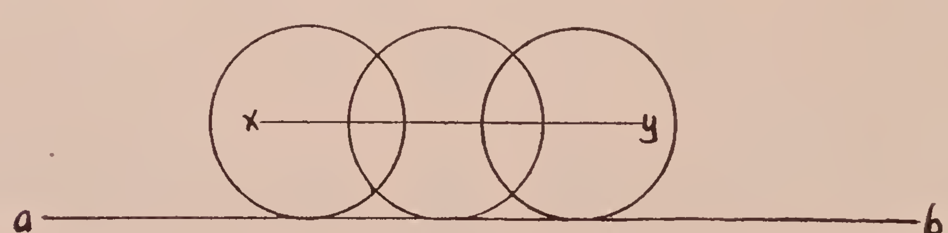


Fig. 95. The locus of centers of circles tangent to a line.

The locus of the center of a circle of given radius tangent to a line is a line parallel to the given line and one radius distant on either side. Figure 95 shows a line parallel to the given line, A-B in which centers of all circles on top of this

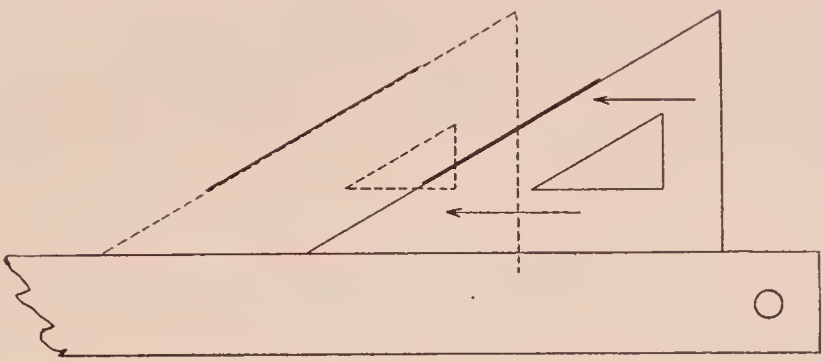


Fig. 96. Method of drawing a line parallel to a given line.

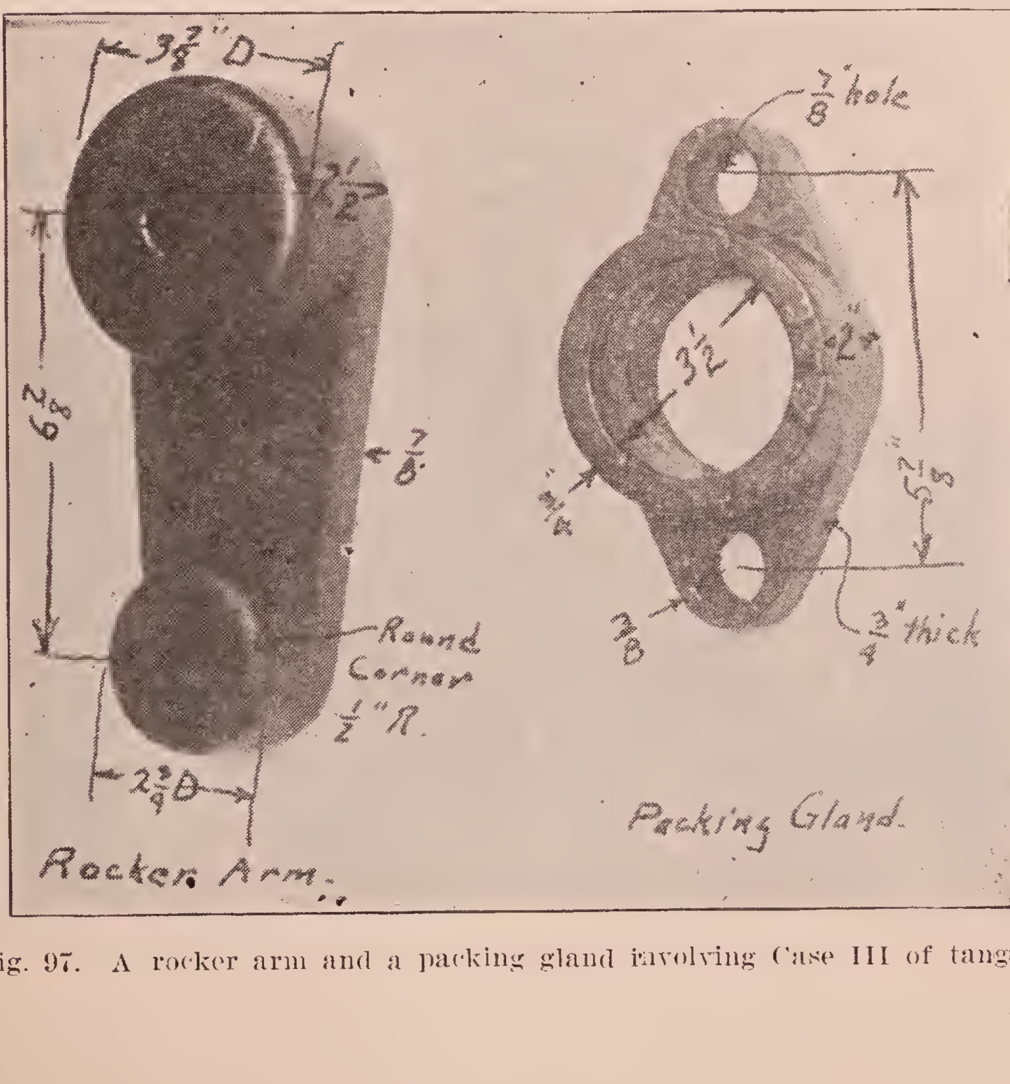


Fig. 97. A rocker arm and a packing gland involving Case III of tangents.

line tangent to the given line are located. Thus, in figure 94, with the two lines A-B and C-D given, step off from each line with the dividers the distances "R." Through the points thus located, draw lines x-y and m-n (See Figure 96) paralled to A-B and C-D respectively; where these lines intersect is the center of the one circle tangent to both lines.

This requires a knowledge of another "trick of the trade" of mechanical drawing. *To draw a line parallel to a given line, set either triangle on any straightedge so that any side of the triangle coincides with the line; slide the triangle on the straightedge and any line drawn on the same edge will be parallel with the given line.* (See Figure 96.)

This case of tangents is very common. Too frequently all of the work of locating centers of circles and tangent points is done by guess. This is often an admission on the part of the draftsman of a lack of knowledge of geometry, and of a careless nature.

Drawing No. 26. Draw two views of the packing gland or rocker arm, Figure 97.

Drawing No. 27. Draw two views of either problem shown in Figure 98.

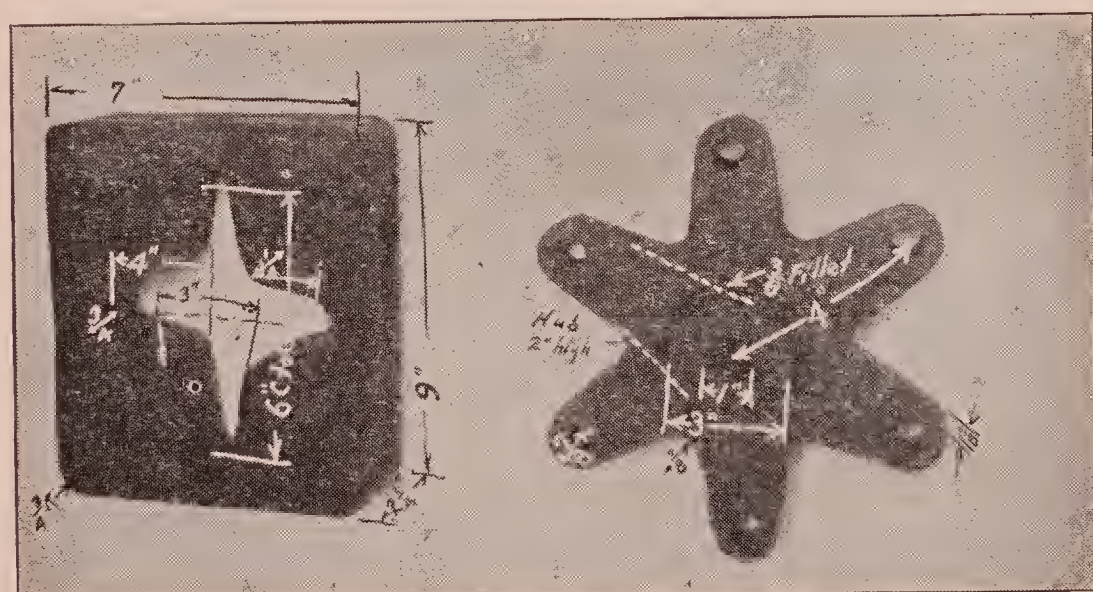


Fig. 98. A flask weight and a web for a reel.

CHAPTER XXVI

Tangent Problems, Case IV

When a circle is tangent to a line and another circle. This case is shown in Figure 99. This figure shows the line

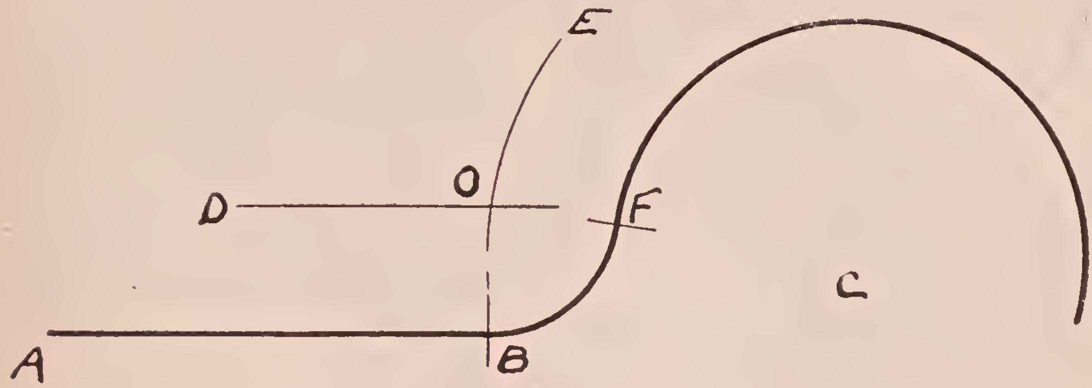


Fig. 99. When a circle is tangent to a line and a circle.

A-B and the circle with center at C. The smaller circle, BF, with its center at O is tangent to the line and the circle.

The locus of the center of circles tangent to a given circle is another circle with the same center and radius equal to the sum of the radii of both circles. Figure 100 shows a concentric circle outside the given circle, with the same center, which contains the centers of all circles of the given radius which will be tangent to the given circle. Thus the intersection of the line, D O in Figure 99 with the circle, B O E, will be the center of the one circle tangent to both the line A B and the circle whose center is at C. The distance from A-B to the line D O and from the given circle to the outer circle should be stepped off with the dividers.

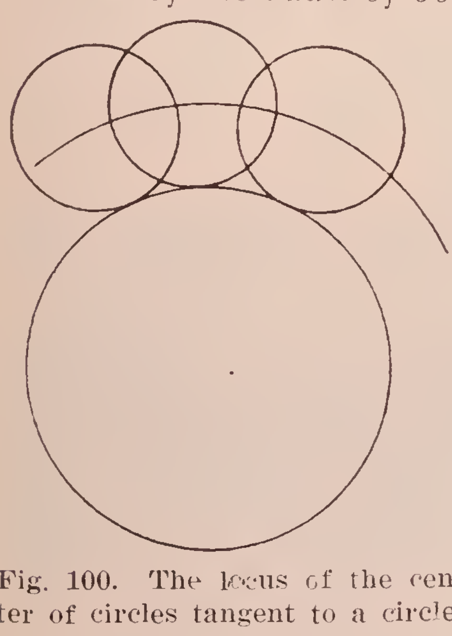


Fig. 100. The locus of the center of circles tangent to a circle.

When two circles are tangent, the point of tangency is located by joining the two centers with a straight line.

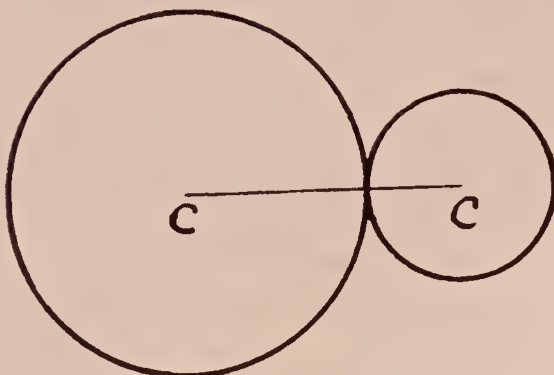


Fig. 101. When two circles are tangent, draw a line of centers to locate the point of tangency.

This is shown in Figure 101. So in Figure 99 join the centers O and C to locate the point of tangency, F. When inking, draw the circles first and then draw the lines joining the circles.

Handwheels and pulleys form a splendid example of this case of tangents. Hand wheels apply all of the tangent problems so far considered.

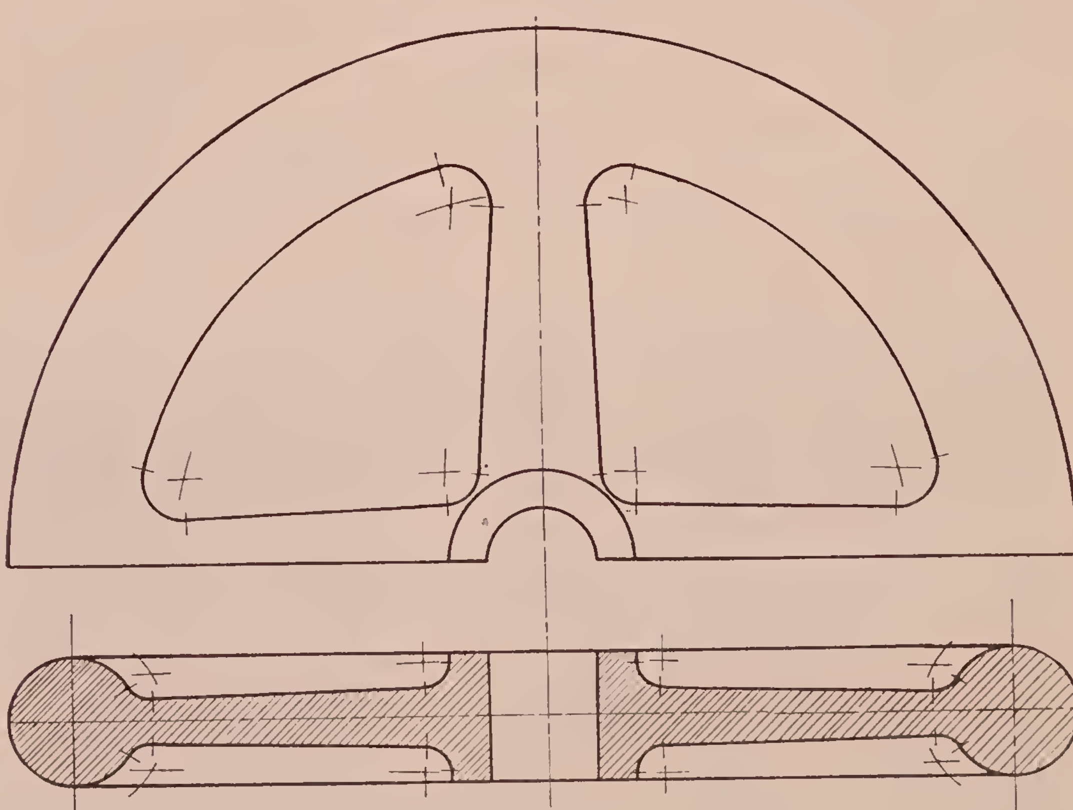


Fig. 102. A hand wheel showing location of 28 points of tangency.

In Figure 102 the sectional view cuts through a spoke and the spoke is sectioned. The conventional representation

of wheels is shown in Figure 103 in which the spoke is not sectioned. This method is used even when the spoke apparently should be sectioned.

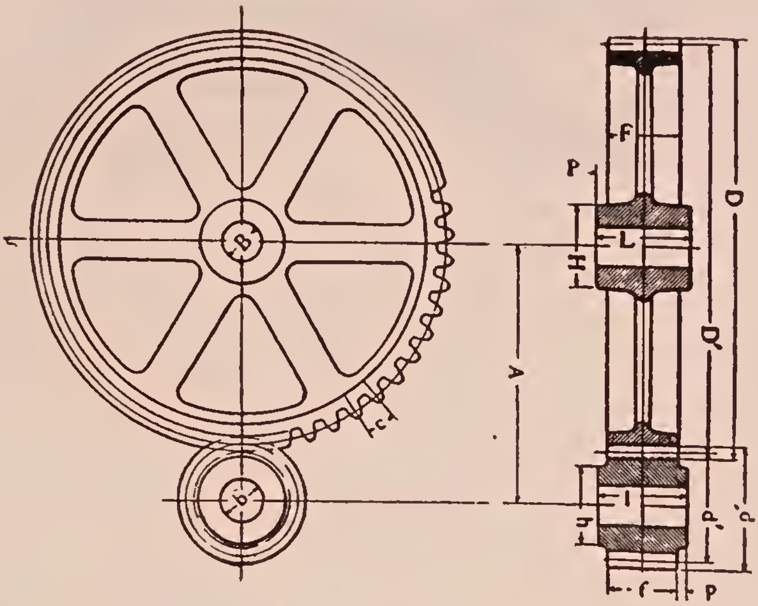


Fig. 103. Handwheels and pulley sections do not always cut spokes. Time in drawing cross-hatch lines is thus saved.

Drawing No. 28. Draw three views of either problem in Figure 104 or Figure 104a.

Drawing No. 29. Draw full front view and full section of right view of any handwheel given in table below. Handwheel rim is round and there may be four or six spokes. (See Figure 102) Draw half of face view in large sizes.

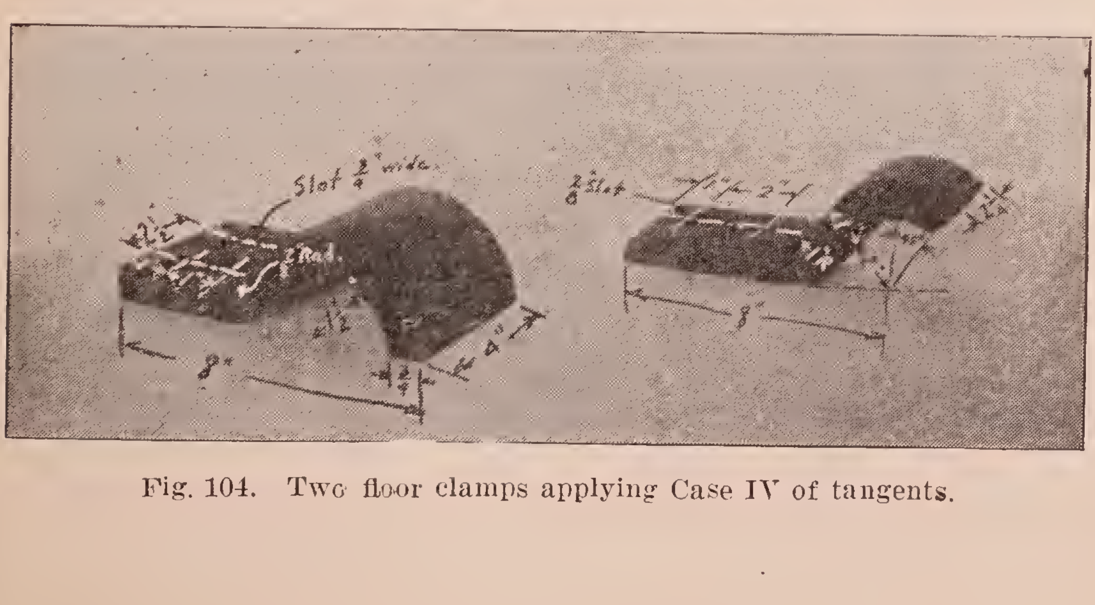


Fig. 104. Two floor clamps applying Case IV of tangents.

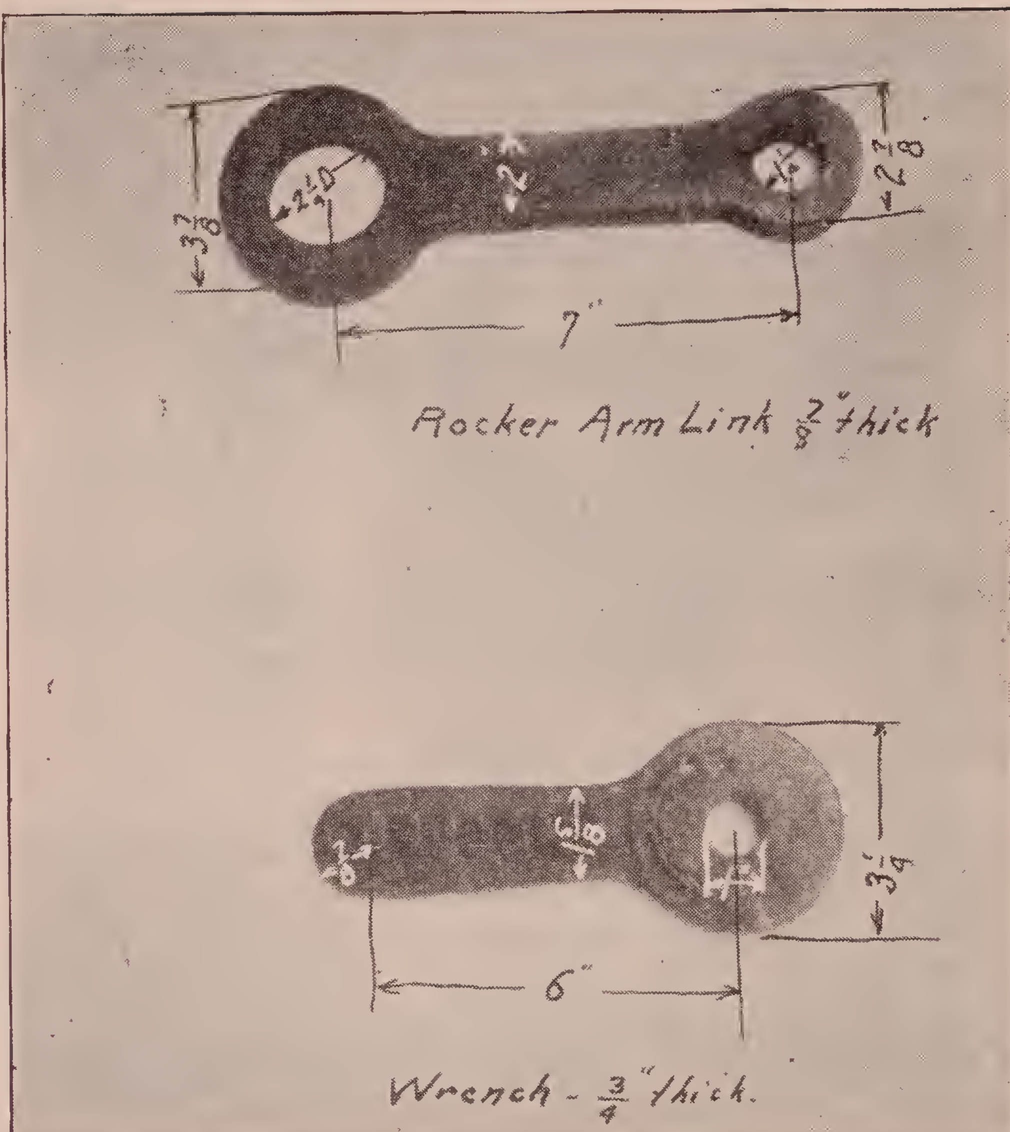


Fig. 104a. A rocker arm and a wrench.

Table of Sizes of Handwheels

Diameter of wheel	Spoke at rim	Spoke at Hub	Diameter of Hub	Diameter of rim	Diameter of round hole in Hub	Thickness of Hub
6	$\frac{5}{16}$x$\frac{5}{8}$	$\frac{1}{2}$x $\frac{7}{8}$	$1\frac{3}{16}$	$\frac{15}{16}$	$\frac{9}{16}$	$1\frac{7}{8}$
7	$\frac{5}{16}$x$\frac{5}{8}$	$\frac{1}{2}$x $\frac{7}{8}$	$1\frac{3}{8}$	1	$\frac{11}{16}$	$1\frac{1}{2}$
8	$\frac{3}{8}$x$\frac{3}{4}$	$\frac{5}{8}$x1"	$1\frac{1}{2}$	$1\frac{1}{16}$	$\frac{7}{8}$	2
9	$\frac{13}{32}$x$\frac{13}{16}$	$\frac{5}{8}$x$1\frac{1}{8}$	$1\frac{5}{8}$	$1\frac{1}{8}$	1	$2\frac{1}{8}$
10	$\frac{7}{16}$x$\frac{7}{8}$	$\frac{11}{16}$x$1\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{3}{16}$	1	$2\frac{1}{4}$

CHAPTER XXVII

Tangent Problems, Case V

When a circle is tangent to two other circles. This problem may occur having either the two circles or the tangent circle given. The contrast is represented in Plates XVIII and XIX. The solution of the second problem on Plate XVIII is shown in Figure 105. The two circles with centers at C and C and the one with the center at O are given. The problem is to locate the center of a circle with radius R which will be tangent to the C circle and the O circle. Set the dividers at a distance R and step off outside the O circle on a radius extended, O M, the distance R. This distance is stepped off three times, once on each circle. It must be measured on a radius extended because otherwise it would not be accurate.

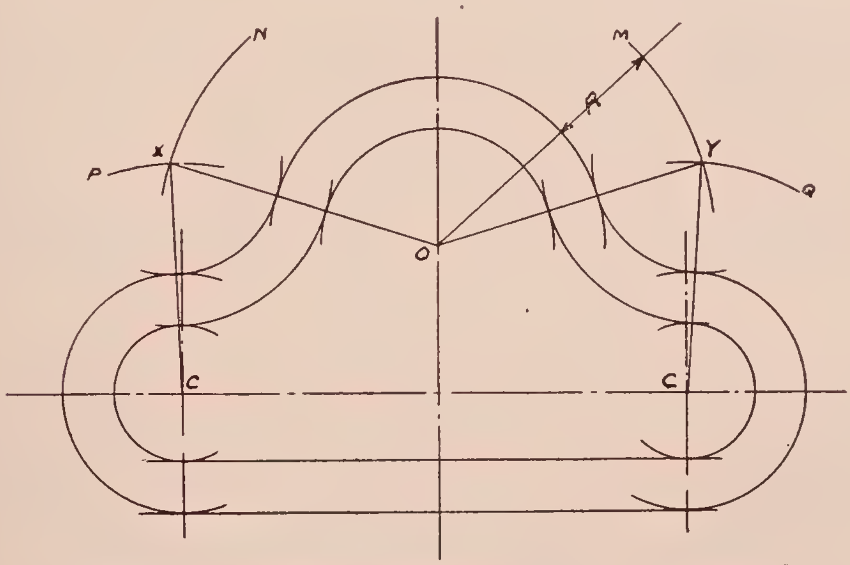
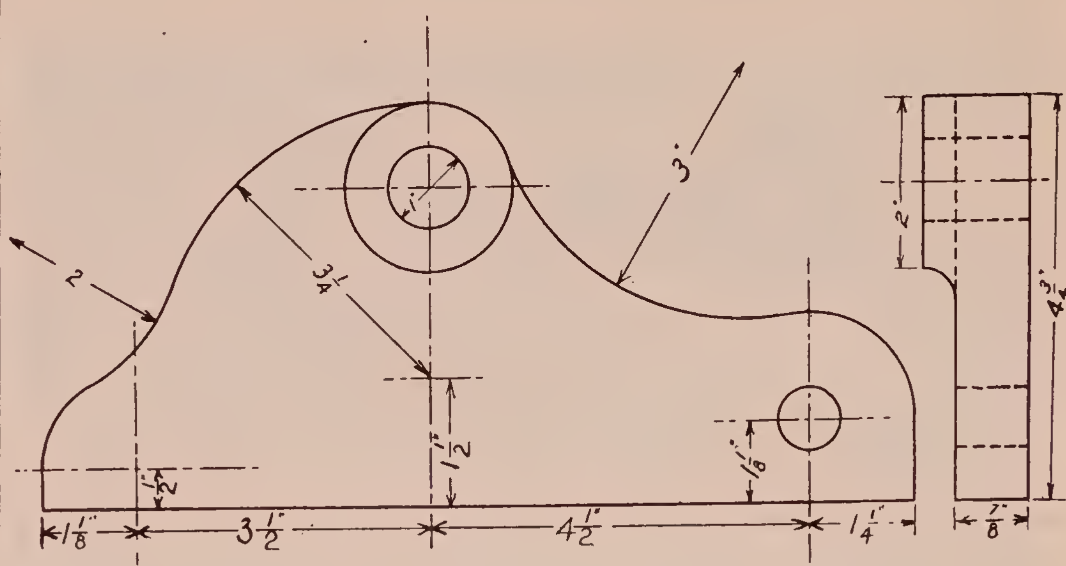
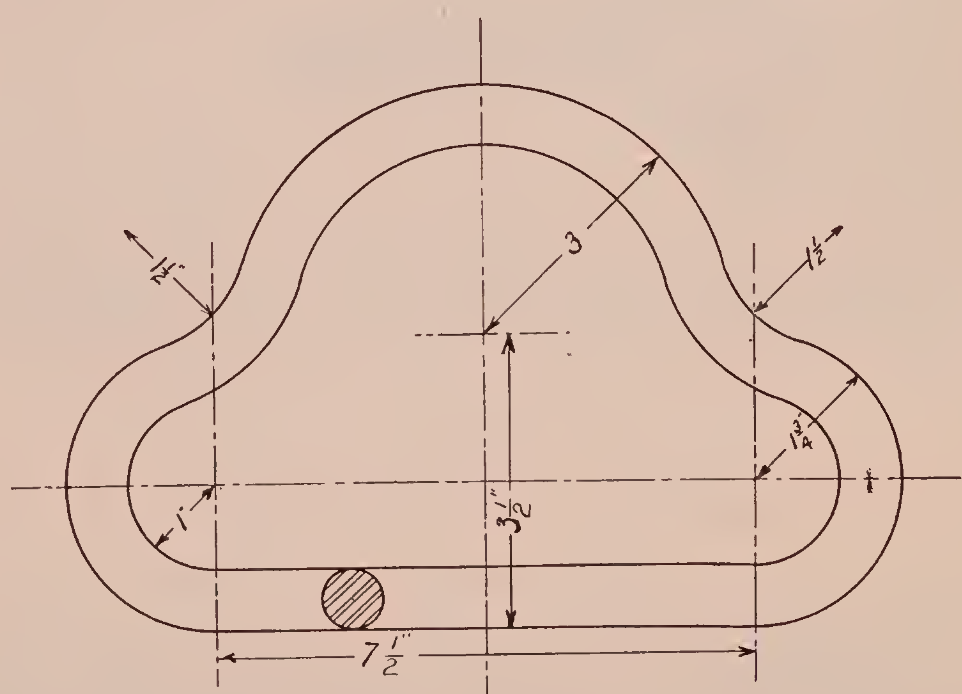


Fig. 105. Solution of problem given on Plate XIX.

With compass set at centers C, C and O, draw arcs of circles P X, Y Q, X N and M Y through the points located with divider. The intersections Xand Y will be centers of



BEARING PLATE.



SLIP LINK FOR A CHAIN

Plate XVIII. Tangent Problems Case V.

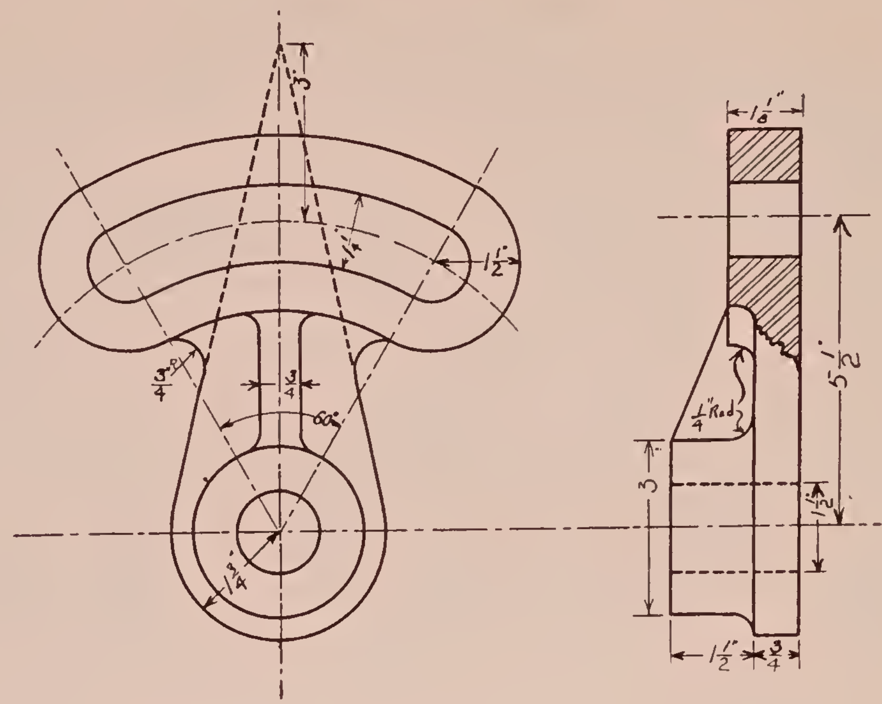
the only circles of the given radius which will be tangent to both circles.

To locate the points of tangency, draw the line of centers, X C, Y C, X O and Y O. In inking this problem, first ink the circle with center at O, then ink circles with centers at X and Y, inking from the ends of arcs previously drawn. Then ink circles with centers at C and C, inking from end of arcs already completed. Lastly, ink the horizontal lines joining the bottom of circles whose centers are C and C.

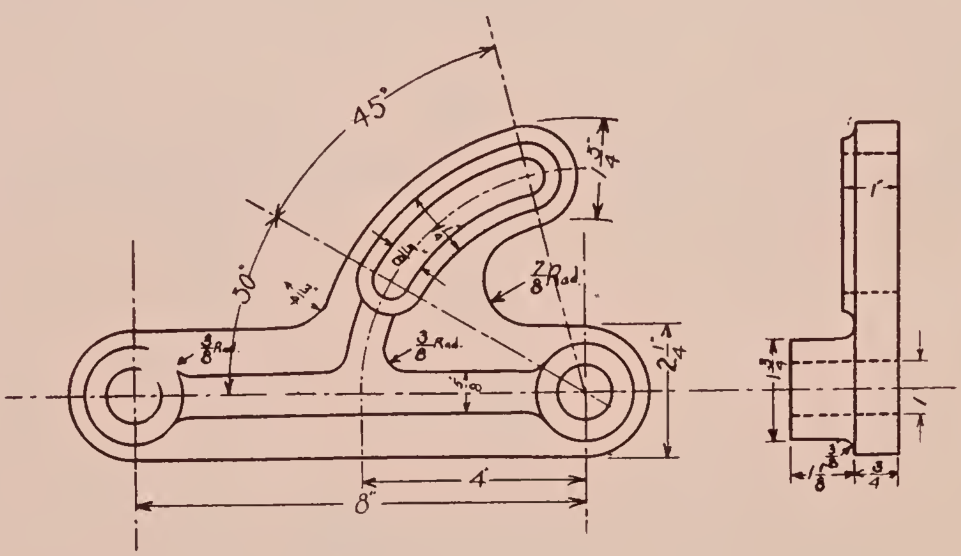
For correct use of the dividers in laying out lengths, refer to Chapter XXIX on Thread Drawing. The use of compasses and dividers invites a very wrong practice, that of punching large and unsightly holes through the paper. This should be avoided as much as possible; very small holes will be covered by the inked lines, but large holes punched through the paper are inexcusable. This is particularly true of centers of tangent circles which are never hidden by intersecting center lines, but are out in the open spaces of the sheet.

Drawing No. 30. Draw three views of either problem given in Plate XVIII. Dimension the drawing and make a tracing.

Drawing No. 31. Reproduce on a regular sheet, either problem given in Plate XIX. Dimension the drawing.



TIGHTENER FOR CHAIN



SWING TYPE OF CHAIN TIGHTENER

Plate XIX. Tangent Problems Case V.

CHAPTER XXVIII

The Helix

A helix is the path which a point makes on a cylinder when the cylinder is revolving at a uniform rate of speed and the point moves parallel to the axis of the cylinder at a uniform rate of speed. When the machinist begins to cut a thread on a bar of iron 2¼'' in diameter, he sets the gears of the lathe so that for every full revolution of the cylinder, the point of the thread-cutting tool moves along parallel to the axis just ¼″. The point of the tool traces a true helix on the face of the cylinder.

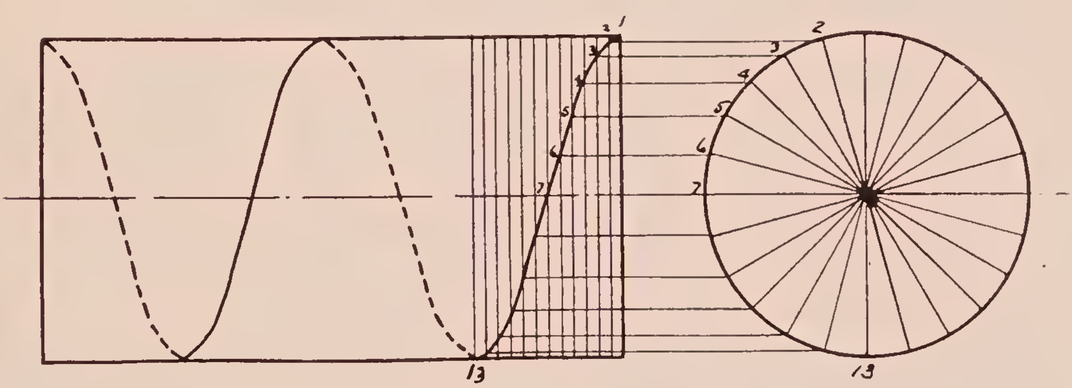


Fig. 106. A helix of two revolutions.

In Figure 106 we see the front and right views of a cylinder. A helix having a pitch of 2″ has been drawn. The pitch of a helix is the distance it advances along the cylinder in one revolution. The first one-half revolution 1-13 is visible and is plotted by dividing the end view circle into twenty-four parts. (See Figure 171, Chapter XLVI). The pitch of the helix is also divided into twenty-four parts or the first half revolution is divided into twelve parts. The helix starting at the point 1, advances 1/12″ when it is even with point 2 in the right view. Thus, the points 1, 2, 3, etc. are plotted. After the points are located, the curve is drawn with a curve called

a French or irregular curve. This helix is symmetrical so that when a place on the irregular curve is found to fit one

Fig. 107. French or irregular curves.

end, mark it with a pencil, and use the same part of the irregular curve on the other end of the helix.

When one-half of a complete revolution of the helix is plotted and drawn, a templet is made so that the other parts of the helix may be drawn exactly the same and without the necessity of plotting each of them. The templet is made of very thin, soft wood and should be made by placing the wood over the drawing and after drawing lines 1-1, 2-2, 3-3, etc. in Figure 106, step off from the points 1, 2, 3, etc. an equal space, using the dividers, on to the wood. Then the curve may be drawn through these points. By using the templet

Fig. 108. Templet made of 1/16″ wood stock for a helix in figure 106.

the remaining portions of the helix may be drawn. Each alternate half of the helix will be invisible and should therefore be represented by dotted lines.

The helix is a very common curve in machine parts and tools. Helical springs or coil springs typify a practical use

of the helical curve. Auger bits and drill bits show helices in each face view. Conveyors are another type of use of the helix.

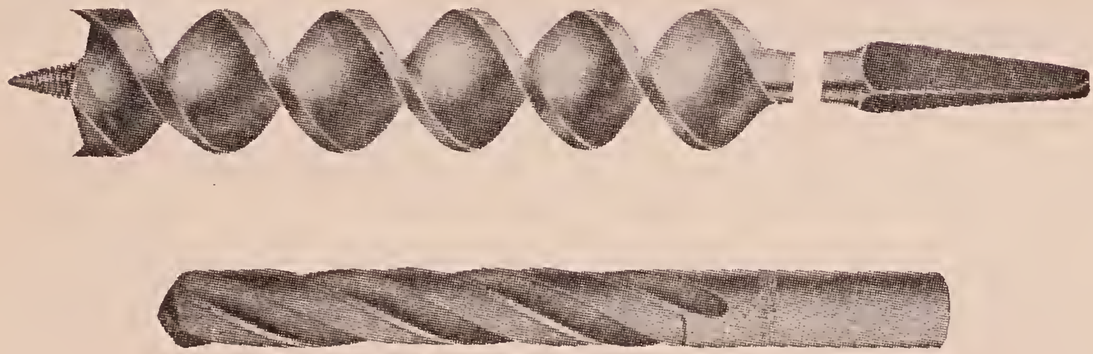


Fig. 109. Auger bits and twist drills show the helix and its application.

All screw threads are helical in their real representation. The face view of every thread will show curved lines for the root or point lines of the thread. Figure 110 shows an actual photograph of a large thread on the drive shaft of a Fordson Tractor, in which the curve of the root and point lines is apparent, so that an actual and true representation of these

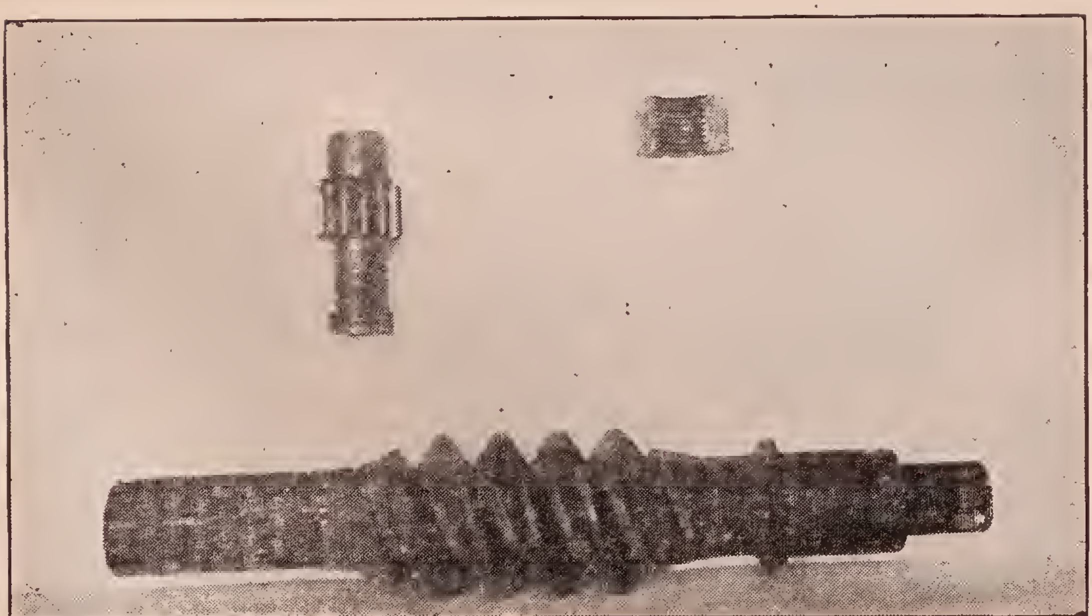


Fig. 110. Drive shaft of a Fordson Tractor showing large threads.

threads would require that the helix for the point line and the helix for the root line be plotted. Yet in most actual representation these lines are drawn as straight lines.

Drawing No. 32. Draw two views of a cylinder $4\frac{1}{2}''$ in diameter and $8''$ long, and draw three revolutions of a helix having a pitch of $2\frac{1}{2}''$.

CHAPTER XXIX

"V" Threads

There are two common forms of the "V" threads, the sharp "V" and the U. S. Standard. The first is the theoretical shape and forms the basis for representing all "V" threads. The second is the practical thread found on all bolts and in all nuts using "V" threads.

Pitch is the distance from the center of one thread to the center of the next. This is true for single, double, or multiple threaded parts. *The lead of a screw is the distance the nut will move when turned a full revolution.* Pitch and lead are equal for single-threaded screws. The lead is twice as great as the pitch in a double-threaded screw, etc. *The number of threads per inch equals one divided by the*

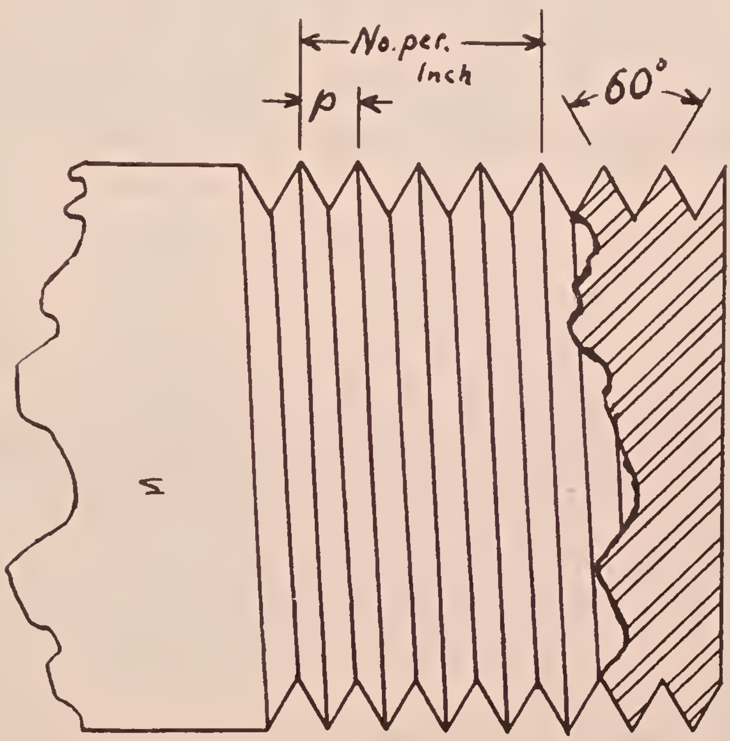


Fig. 111. The sharp "V" Thread.

pitch. Thus on a 1″ bolt the threads are 1/8″ apart, so there are eight threads per inch.

The sharp "V" thread is made with the point and root an acute angle, each being 60°. (Figure 111) For various standards of threads, all bolts of the same size have the same number of threads per inch.

The U. S. Standard Thread is similar to the sharp "V" except that the tops or points and the roots are flattened to 1/8 the entire depth of the thread. (Figure 112) This makes the cutting of the thread easier. The thread-cutting tool does not become dull so easily. It also does not interfere with the strength of the bolt and thread.

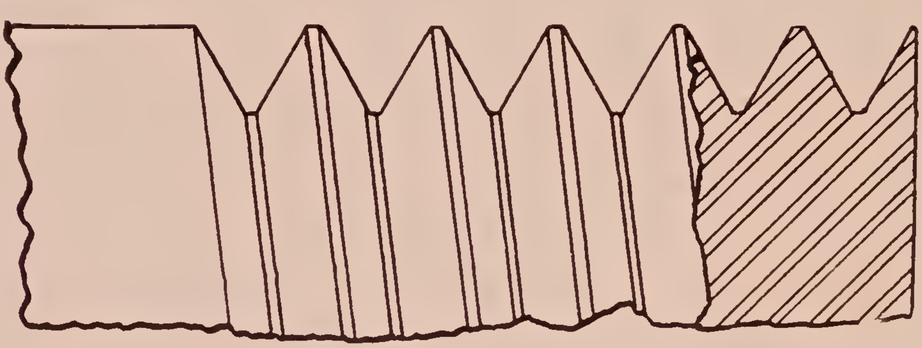


Fig. 112. The U. S. standard thread.

The following order should be followed when drawing the "V" thread (See Figure 113.)

a. Lay off number of points per inch on one side of rectangle representing side view of cylinder.

b. Use 60° triangle and draw one side of sharp Vs.

c. Draw other side of Vs.

d. Project from roots of these Vs to get points on other side of rectangle.

e. Draw Vs on other side of rectangle.

f. Draw all lines of points, sliding triangle on tee square to draw them parallel.

g. Draw all lines of roots same way. Root lines are *not* parallel to point lines.

h. Project root bottom to end view and draw dotted circle representing bottom of thread.

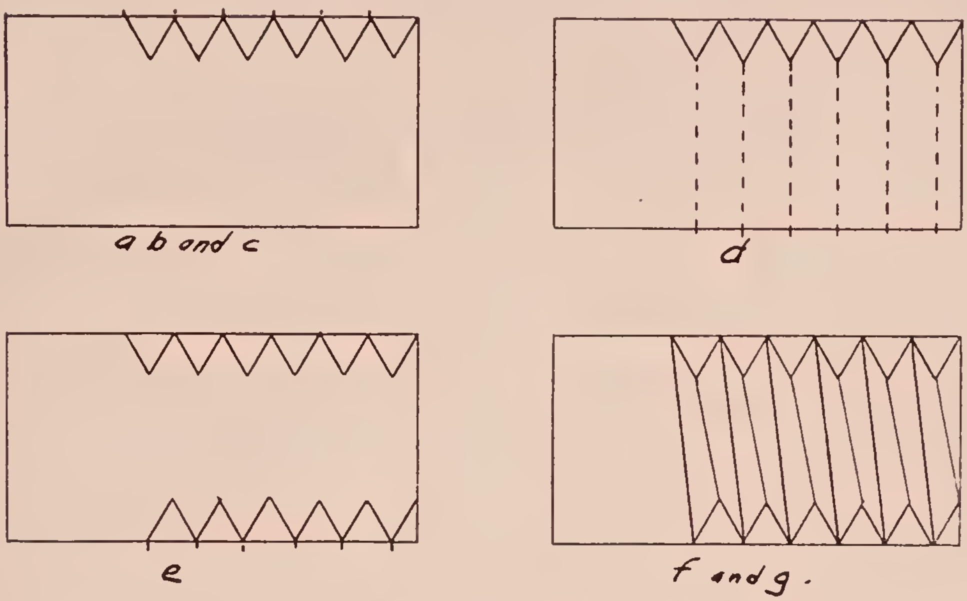


Fig. 113. Method of drawing "V" threads.

When laying off points of the threads, if the pitch equals ½, ¼, ⅛, 1/16, 1/12 part of an inch, or when the pitch is found on the scale, use the scale for locating points. Thus, on the 2½″ bolt there are four threads per inch. Lay off the points ¼″ apart. When there is an odd number of threads per inch such as 5, 7, 9, 11, etc. use the dividers for locating the points. First lay off each inch point on one edge of the cylinder. Then on the waste edge of the sheet, lay off

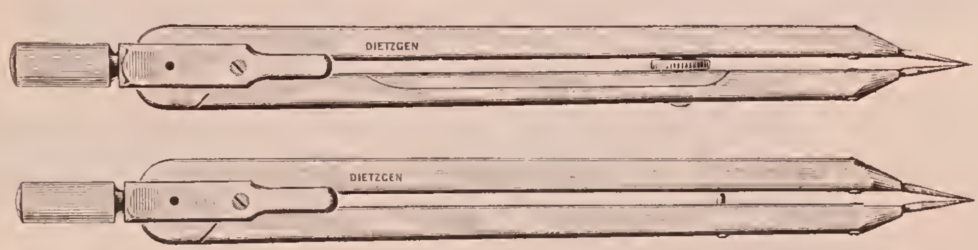


Fig. 114. The dividers, plain and hairspring types.

one inch and set dividers so they will step off the required distance. Step this off on the sheet, being careful not to punch holes through the paper. Punch small holes, holding

the dividers at an angle of 15° to 30° to surface of paper; the pencil lines will then cover holes. Dividers are so called because of their use; to divide an inch into 3, 7, 9 parts, etc. When there are 3½ threads per inch, divide a 2″ length into 7 parts and lay off points.

After the points are laid out, the sides are drawn and the points on the opposite side are found. In a single pitch thread, roots are opposite points and points are opposite roots. To sketch a "V" thread draw two rail fences with each opposite rail parallel. (See a, Figure 115.) Keep

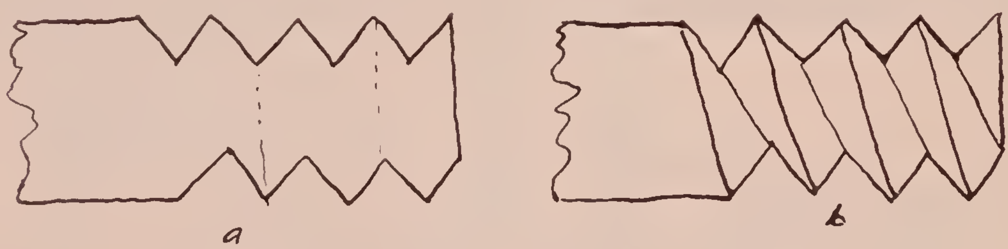


Fig. 115. Sketching a single-thread sharp "V" screw.

points opposite roots and roots opposite points. After the two sides are drawn, join all points, then join roots. Notice that root lines and point lines (See b, Figure 115) are not parallel. These are never parallel and should not be so drawn.

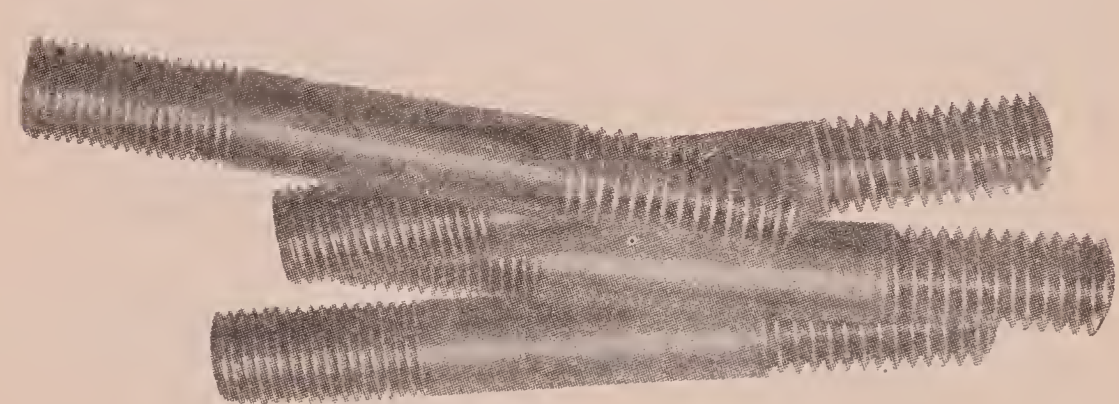


Fig. 116. Stud bolts.

Sharp "V" threads appear best when the outline of threads and point and root lines are drawn. Several conventional methods of representing them are permissible. In

Plate XX the top screw shows threads in profile while the stove-bolt in the bottom of the bowl shows a conventional representation of sharp V threads. Figure 76 shows the threads on the grinder shaft in a conventional representation.

One of the simplest thread drawing problems is the Stud Bolt shown in Figure 116. These bolts are threaded on each end with U. S. Standard threads a distance of 1/3 of the length.

Drawing No. 33. Draw two views each of two stud bolts: one 1″x9″, U. S. Standard eight threads per inch; the other 2½″x9″ U. S. Standard with two threads per inch. The first is a standard thread; the second is too large for the bolt but shows better that root lines and point lines are not parellel.

Drawing No. 34. Draw helical representation of sharp V threads on a 5½″ bolt 9″ long. Draw a half circle representing end view and draw five full threads having a pitch of 1½″. (Similar to Figure 123)

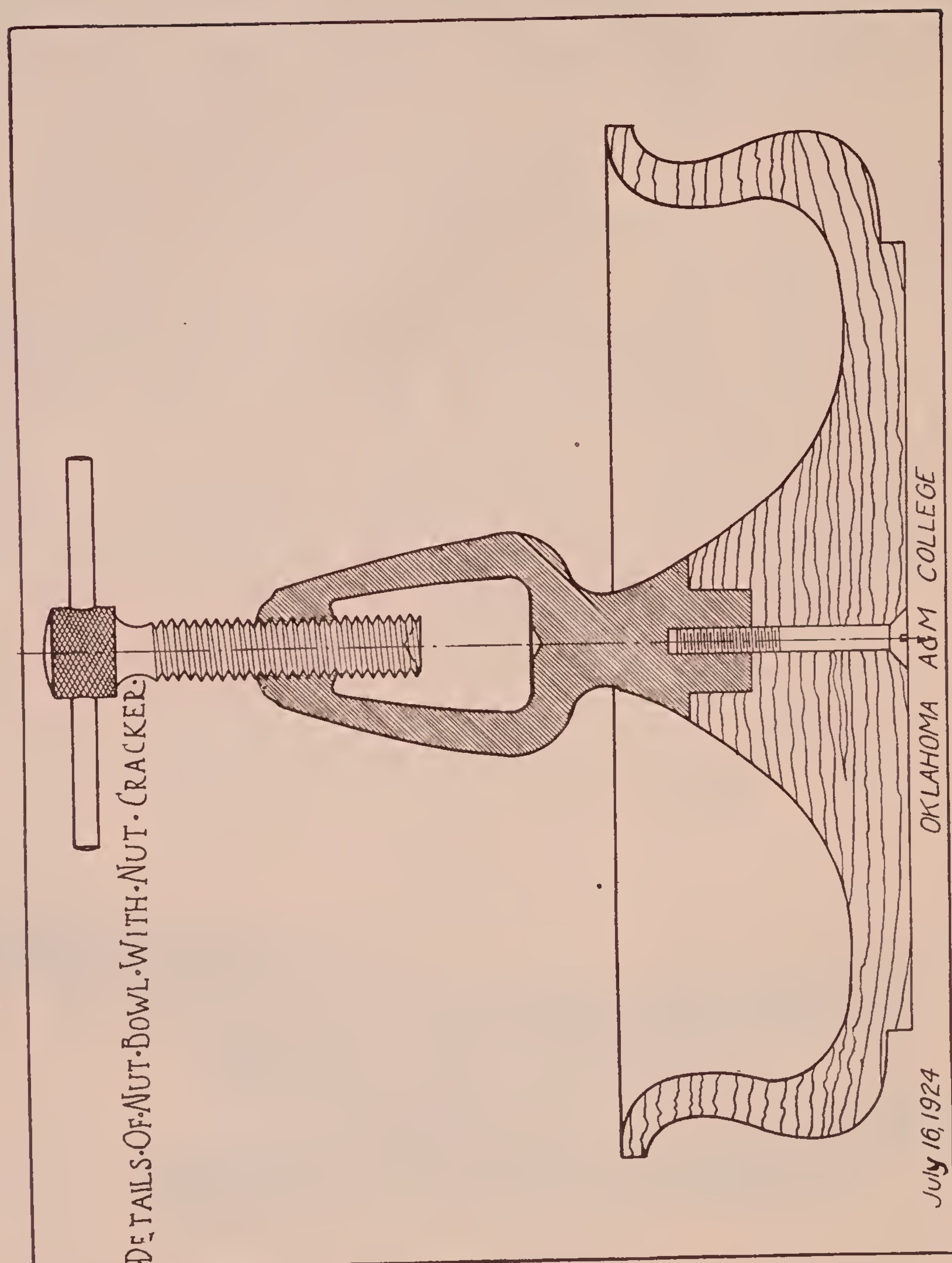


Plate XX. Nut bowl and nut cracker showing thread drawings

CHAPTER XXX

Bolts and Nuts

There are so many kinds of bolts and nuts that it would require many pages to list and illustrate them. Complete details of the commoner types may be found in such reference books as "Machinery's Hand-book." Several kinds, such as Machined bolts, Carriage bolts, and Automobile bolts are common enough to learn to draw. All are drawn in similar ways. The U. S. Standard Machine bolt, which will be described, is typical of all of them.

The sizes of the U. S. Machine bolt are given for different diameters as follows:

Table of Sizes of U. S. Standard Machine Bolt
Square or Hexagonal Heads and Nuts

Diameter	No. Threads	Distance across flats	Thickness of head	Thickness of Nut
1½	6	2⅝	1 3/16	1½
1¾	5	2¾	1⅜	1¾
1⅞	5	2 15/16	1 15/32	1⅞
2	4½	3⅛	1 9/16	2
2¼	4½	3½	1¾	2¼
2½	4	3⅞	1 15/16	2½
3	3½	4⅝	2 5/16	3

From this table the bolt may be drawn, following Plate XXII for methods of representing the chamfer on the nut and head, and for rounding end of bolt.

The number of threads per inch varies for different kinds of threads. The table in Figure 117, shows U. S. Standard,

Standard of thread	Diameters of screw.																							
	5/32	3/16	7/32	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	7/8	1"	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3
US Standard	36	32	28	20	18	16	14	13	12	11	11	10	9	8	7	7	6	6	5	4½	4½	4	4	3½
SAE.				28	24	24	20	20	18	18	16	16	14	14	12	12	12	12						
Stove Bolt.	28	24	22	18	18	16																		
Square and Acme.	No definite standard.																							

Fig. 117. A table comparing the number of threads per inch for different standards.

A. S. M. E. or S. A. E. (Society of Automotive Engineers) Stove bolt, Square and Acme thread standards. This explains why a ¼″ nut of the ordinary variety will not fit on a ¼″ stove bolt.

When drawing threads the slope of point and root lines indicates right or left hand threads. If the nut is advanced on the bolt when it is turned to the right or clockwise, when the individual is facing the end of the bolt, the thread is right hand. If the reverse is true, the thread is left hand. Figure 118 shows sketches of a right hand and a left hand thread. The only difference is in the slope of the point and root lines. One use of left hand threads is on the left end of a grinder. When the grinding wheel turns over and toward the operator, the left hand threads tend to tighten the nut holding the wheel. Other uses are on the right hand wheels of a wagon, the adjusting thumb screw of a jack plane, etc. The split or sectioned nut in Figure 110 apparently shows left hand threads but is in reality the right hand threads in section. This is true also of the nut on Plate XXI.

Fig. 118. A right hand and a left hand thread.

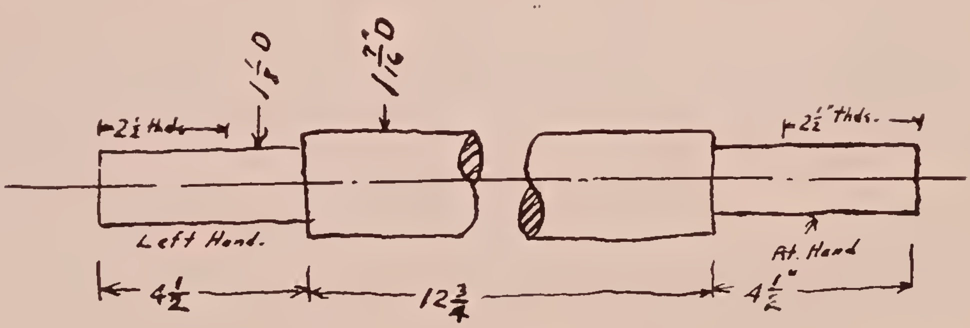


Fig. 119. A grinder mandrel.

Drawing No. 35. Draw two views of the grinder mandrel shown in Figure 119 with right and left hand threads.

Drawing No. 36. Draw two views of a 6″ Machine bolt and nut of any diameter given in table above. Refer to Plate XXI for details.

Drawing No. 37. Draw two views of six kinds of bolts, set screws, cap screws, etc. each ¾″x4″, spacing the problems carefully and securing data as to size, shape of head, etc. from a "Hand-book." (See Figure 120.)

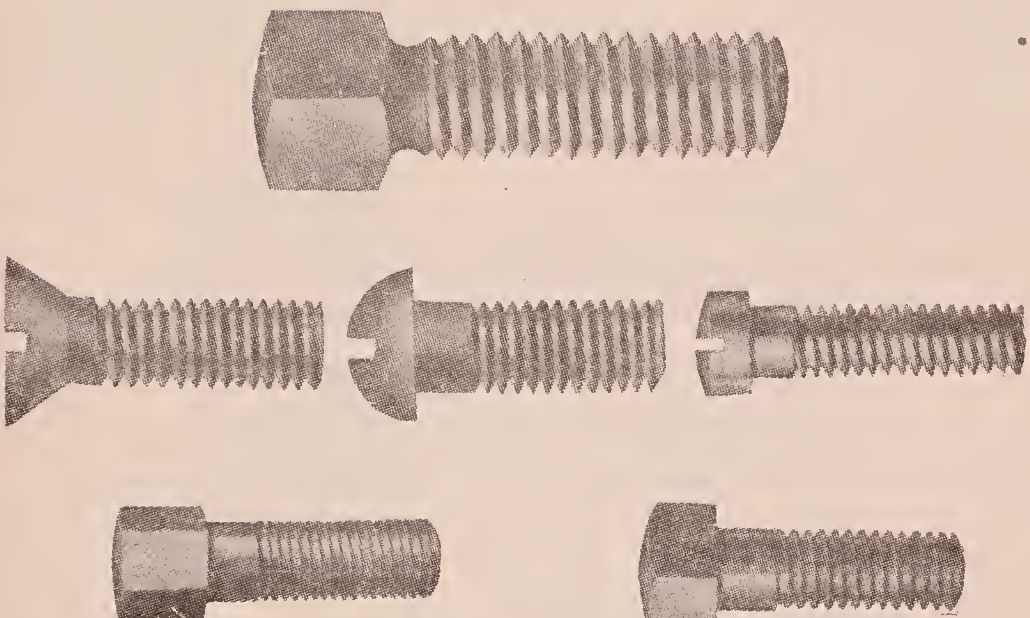


Fig. 120. Six kinds of machine screws: Set screws; counter-sunk, round head and fillister head machine screws, and hexagon and square cap screws.

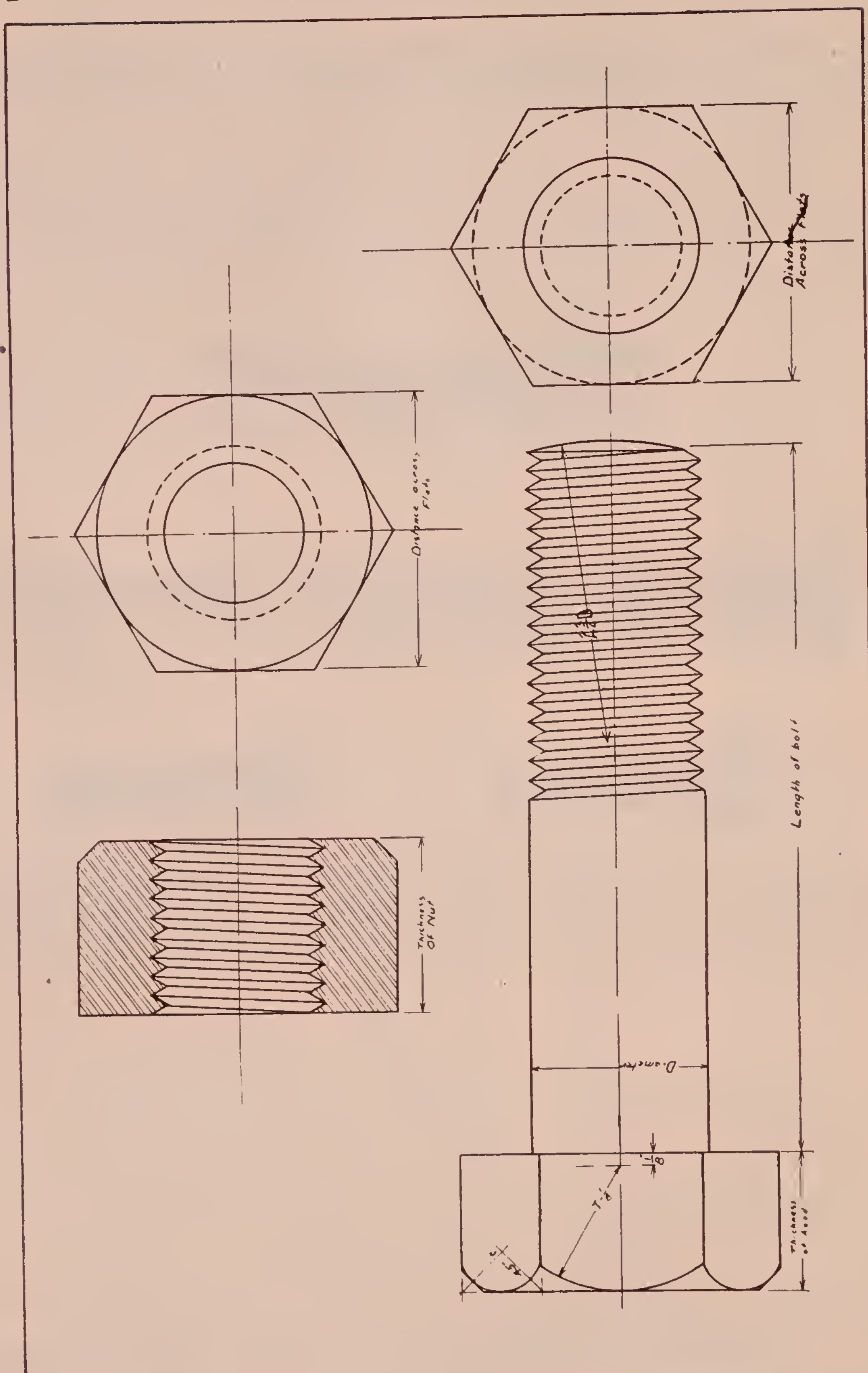


Plate XXI. Detail drawing of a U. S. standard machine bolt.

CHAPTER XXXI

Square Threads

The square thread is so called because the thread profile is practically square. This type of thread is used on jack screws, feed screws on machine lathes, and on machinery where great pressures are exerted. Figure 121 shows the detail of the square thread and a conventional representation nearest to the real thread.

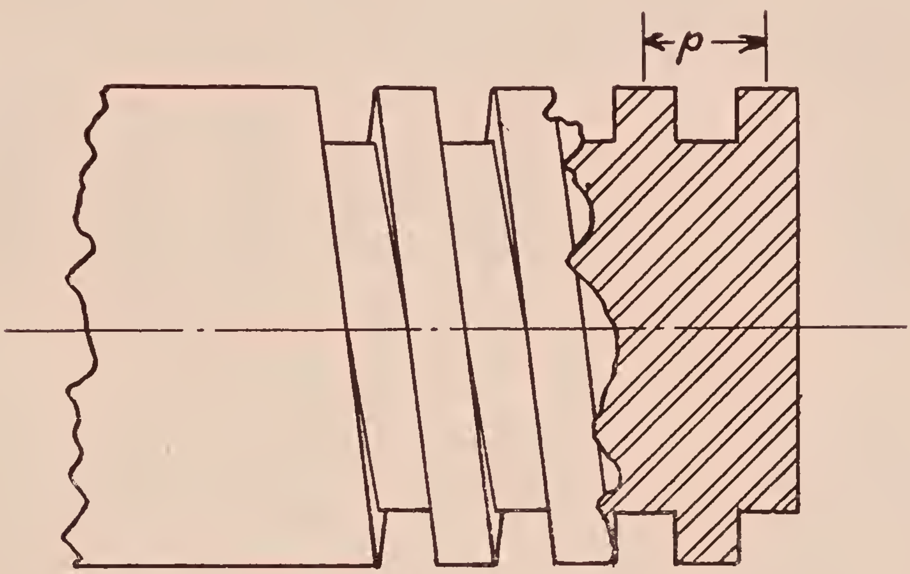


Fig. 121.. The square thread.

Owing to the difficulty of grinding tools to cut a square thread, a varation of it called the Acme Standard has been developed. The sides slope at 29°; otherwise it is similar to the square thread. It is drawn by laying out as for a square thread. (See lower edge of Figure 122). By locating the center of the sides of the squares and drawing 15° slope lines through these points, the thread is completed. All root corner lines are drawn parallel and all point corner lines are also parallel.

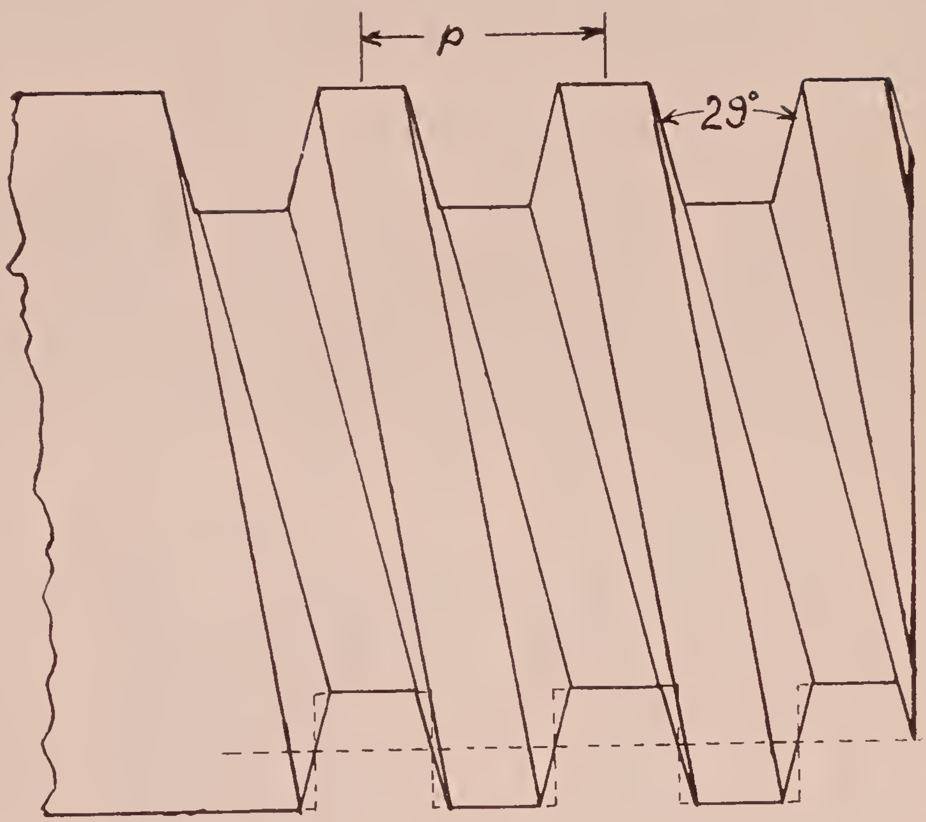


Fig. 122. The Acme standard thread.

The square thread affords a delightful application of helical representation. Figure 123 shows the actual and exact representation of all helices in the square thread. There being four helices, two for point lines and two for root lines, different templets must be made for the drawing.

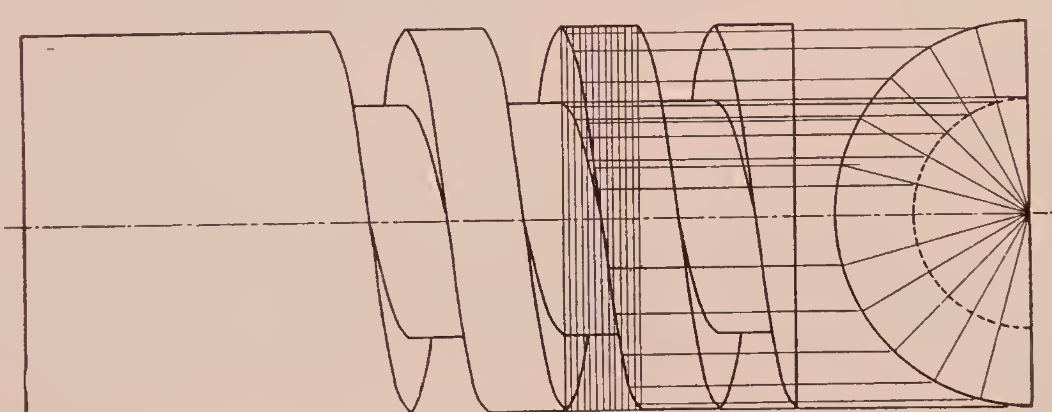


Fig. 123. A true representation of the square thread.

Drawing No. 38. Draw a true representation of four turns of a square thread having a pitch of 1½″ on a 5½″ bolt 9″ long. Make drawing similar to Figure 123.

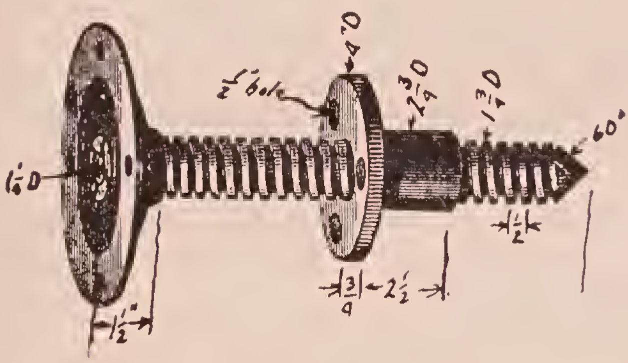


Fig. 124. A screw for an adjustable stool.

Drawing No. 39. Draw two views of screw and two views of nut (one full sectioned) shown in Figure 124. Put both drawings on one sheet and represent threads as shown in Figure 121. Pitch=⅝″. The screw is 10″ long.

Drawing No. 40. Draw two views of the screw in Figure 124, with Acme Standard thread instead of square threads. Make the screw 2½″ in diameter and the pitch ¾″.

CHAPTER XXXII

Double-Triple-Multiple-Threaded Screws

Threads are often made so that in one revolution the nut will advance twice, three times, or four times the amount of the pitch. This is accomplished by actually cutting two, three, or four threads on the bolt. Double-pitch, triple-pitch, etc. are not correct terms, since the pitch be'ng the distance from one thread to another does not change when the lead is doubled or tripled. Double-threaded screws are used in vises. The Bendix drive uses a triple-threaded screw.

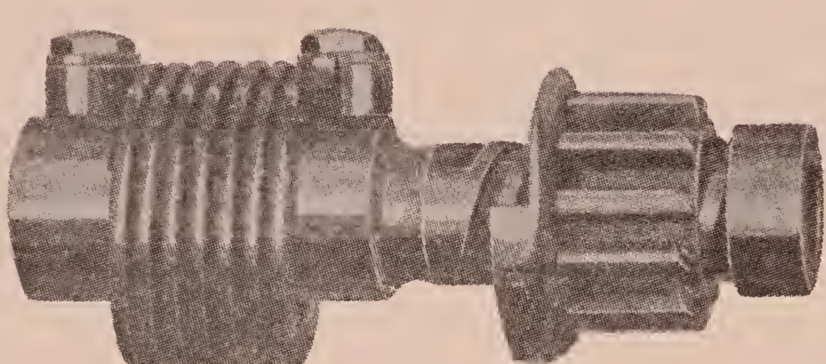


Fig. 125. The Bendix drive showing a use of a triple-threaded screw.

When drawing a double-threaded sharp "V" screw, the Vs on each side are made so that points are opposite points and roots are opposite roots. Figure 126 shows two steps in sketching the double-threaded screw. At the left the Vs

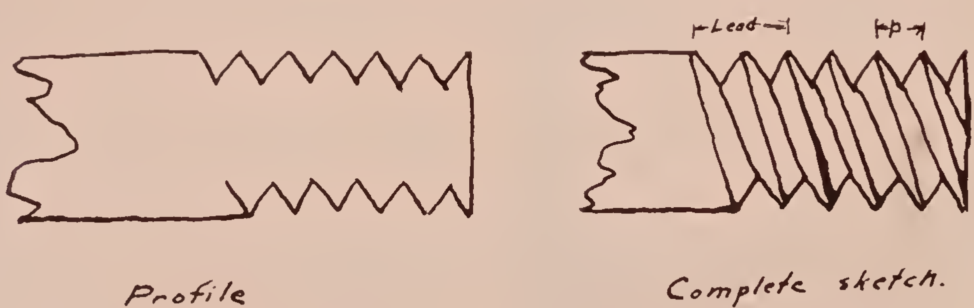


Fig. 126. Method of sketching a double-threaded screw.

are drawn with points opposite points. At the right, the point lines slope an amount equal to the pitch in one half revolution of the screw.

The double-threaded square thread screw affords good practice in thread drawing. Figure 127 shows a good type of representation for a double-threaded square thread screw.

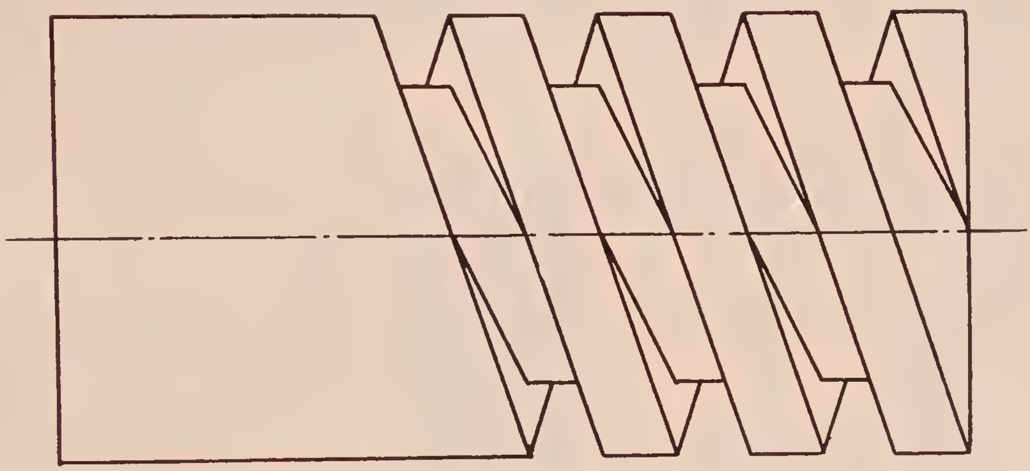


Fig. 127. A double-threaded square thread screw.

Drawing No. 41. Draw the *screw for a veneer press,* Figure 128. It has a double-threaded screw 5/8″ pitch. Make the drawing full size, shortening the front view to a suitable length. (See Figure 129) Length = 22″.

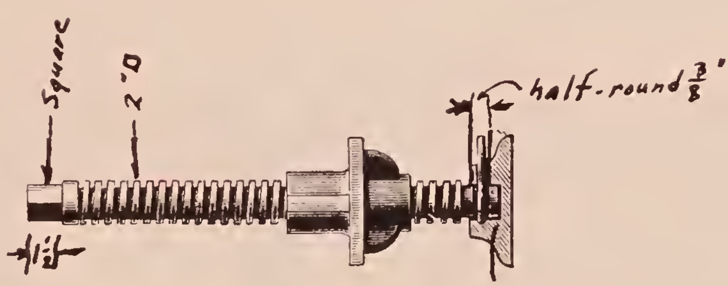


Fig. 128. A screw for a veneer press.

CHAPTER XXXIII

Pipe Threads

Threads on pipe are always made similar to a *sharp* V or U. S. Standard thread. They taper 1/32" per inch on each side of the pipe, so that by screwing the fittings together, a water tight joint is made. The last three or four

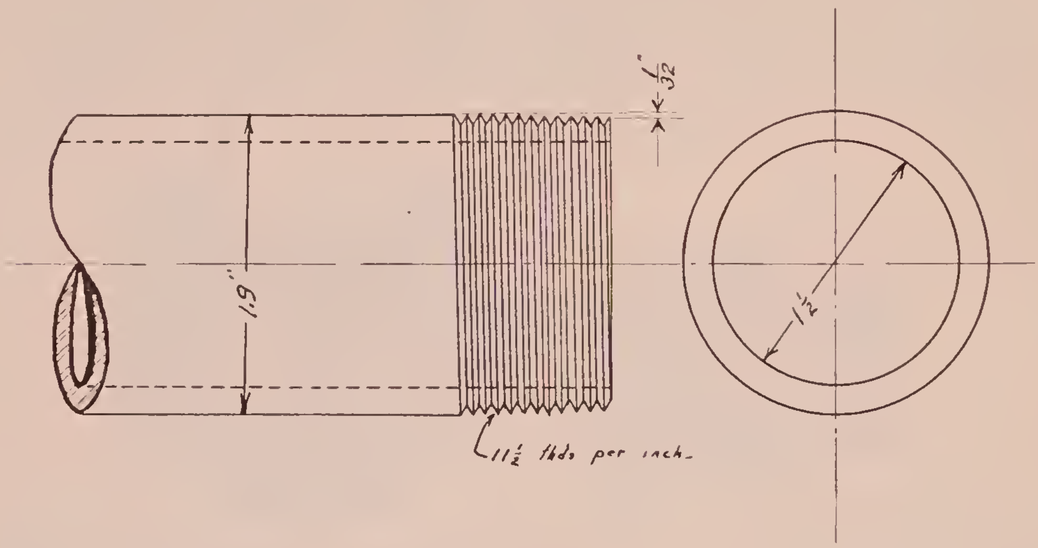


Fig. 129. Pipe threads on a 1½" pipe.

threads are imperfect, due to the need for short threads on the die when starting to cut threads. In drawing the pipe

STANDARD SIZES

Nominal Size	Inside Diam.	Outside Diam.	Threads per Inch
⅛	.269	.405	27
¼	.364	.540	18
⅜	.493	.675	18
½	.622	.840	14
¾	.824	1.050	14
1"	1.049	1.315	11½
1 ¼	1.380	1 660	11½
1 ½	1.610	1.900	11½
2"	2.067	2.375	11½
3"	3.068	3.500	8
4"	4.026	4.500	8

threads, after determining the number per inch, draw the 1/32″ taper and draw all of the threads as though they were perfect. See Figure 129.

Drawing No. 42. Draw two views of a piece of 2½″ pipe, 3′ long showing threads on each end. Secure dimensions from above table. (Shorten front view)

Drawing No. 43. Draw a full section side and end view of a 2″ or a 2½″ globe valve. Borrow one from a plumbing shop to get the measurements.

CHAPTER XXXIV

House Plans

A complete set of house plans consists of a plan of each floor, an excavation or footings plan, and a roof plan. In addition, there must be four elevations, showing each side of the house with details of door and window arrangement and wall construction. Then detail drawings must be made to show all door and window frame construction, roof framing, and all built-in woodwork. These are made in plans and elevations, the latter often showing sectional views. A perspective sketch of the completed building is often made to show the owner just what the house will be like.

The design of a home should include as much built-in work as is permissible. Breakfast nooks, closets, seats, book cases, kitchen cabinets, etc., if built in, make the house more saleable as well as more useful. When planning a home, it is well to plan complete plumbing equipment and also complete electrical service. Plenty of outlets for electric fans, motors, etc. should be provided. Numerous outlets for floor lamps and other lights should also be included in the plans. Two or three outlets for radio aerials and grounds should be installed, but care must be taken not to parallel electric lines with radio circuits.

There are many conventional methods of representing details in house plans. Secure books of details from firms specializing in such works and adopt a good-appearing type of plan and then maintain that style.

Drawing No. 44. Draw the floor plan of your home. Use a scale of $3/8'' = 1'\text{-}0''$.

Drawing No. 45. Draw the roof plan of your home. Use same Scale.

The drawing need not be inked; ink the tracing only.

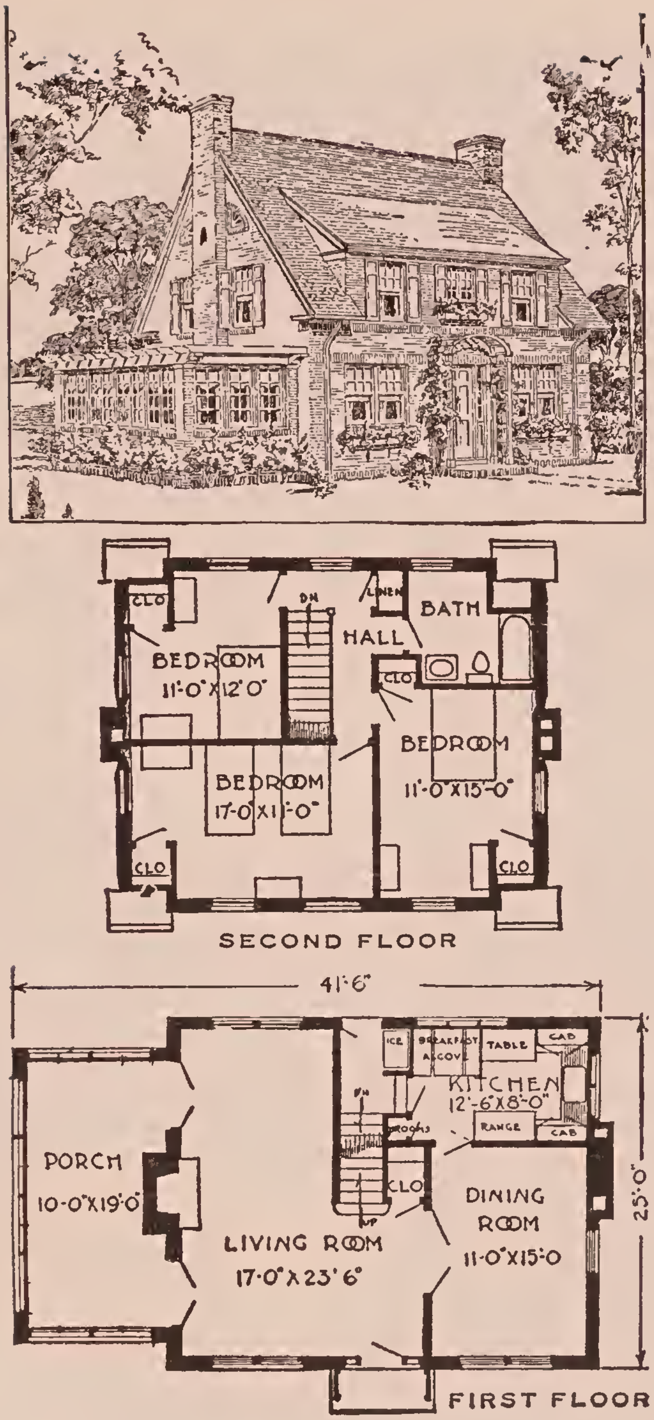


Fig. 130. A two story brick house showing partial arrangement of furniture. Floor plans and perspective sketch are shown.

The first floor plan may be used to assist in making the roof plans.

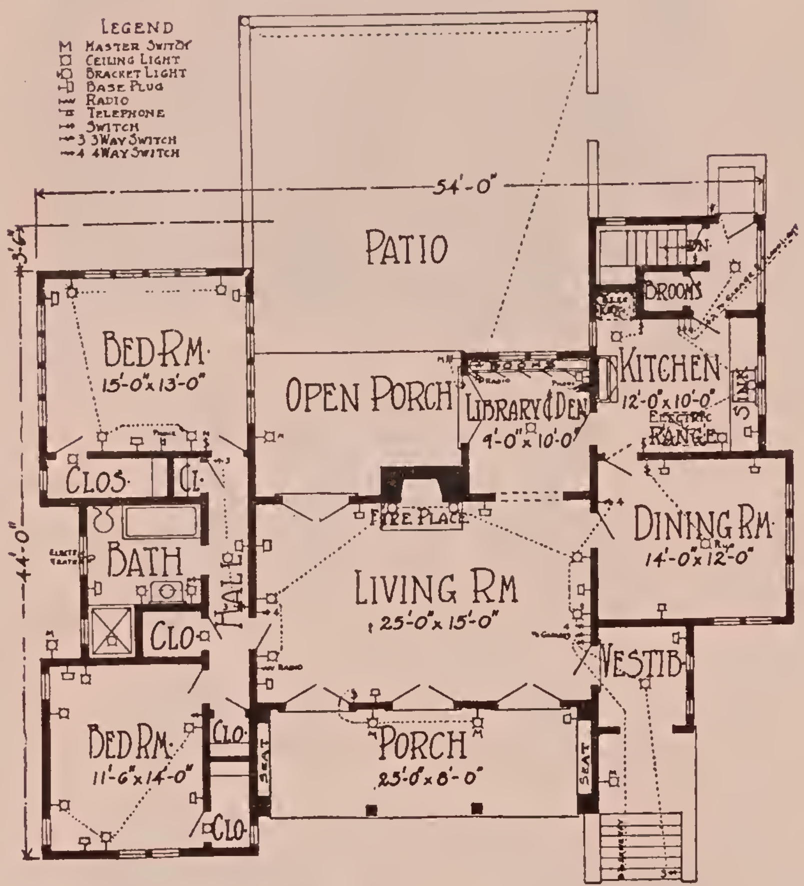


Fig. 131. A floor plan providing for electrical service, from an article by Lee McClure in the "American Builder" for April, 1926. (Used by permission).

Fig. 132. A photograph of the house in Figure 130 after completion.

CHAPTER XXXV

Building Details

Much detail planning must be done after the general floor plans have been decided upon. Sections through foundation, sill, window sill, window head, plate and rafter projection, must be made. Elevation framing details must be worked out. Special problems of framing over wide openings must be solved. Rafter plans for roof detail must be made. These problems must all receive full attention and must be solved in scale drawings before a contractor can make an accurate estimate of the cost of the job.

Details of window and door frames can best be obtained from Millworks catalogs. These are more or less standard and should be kept so in the plan. Visit and study houses under construction to determine standard practices in common use.

Drawing No. 46. Plan and make detail construction drawings for a two car garage. Plates XXII and XXIII show typical detail plans.

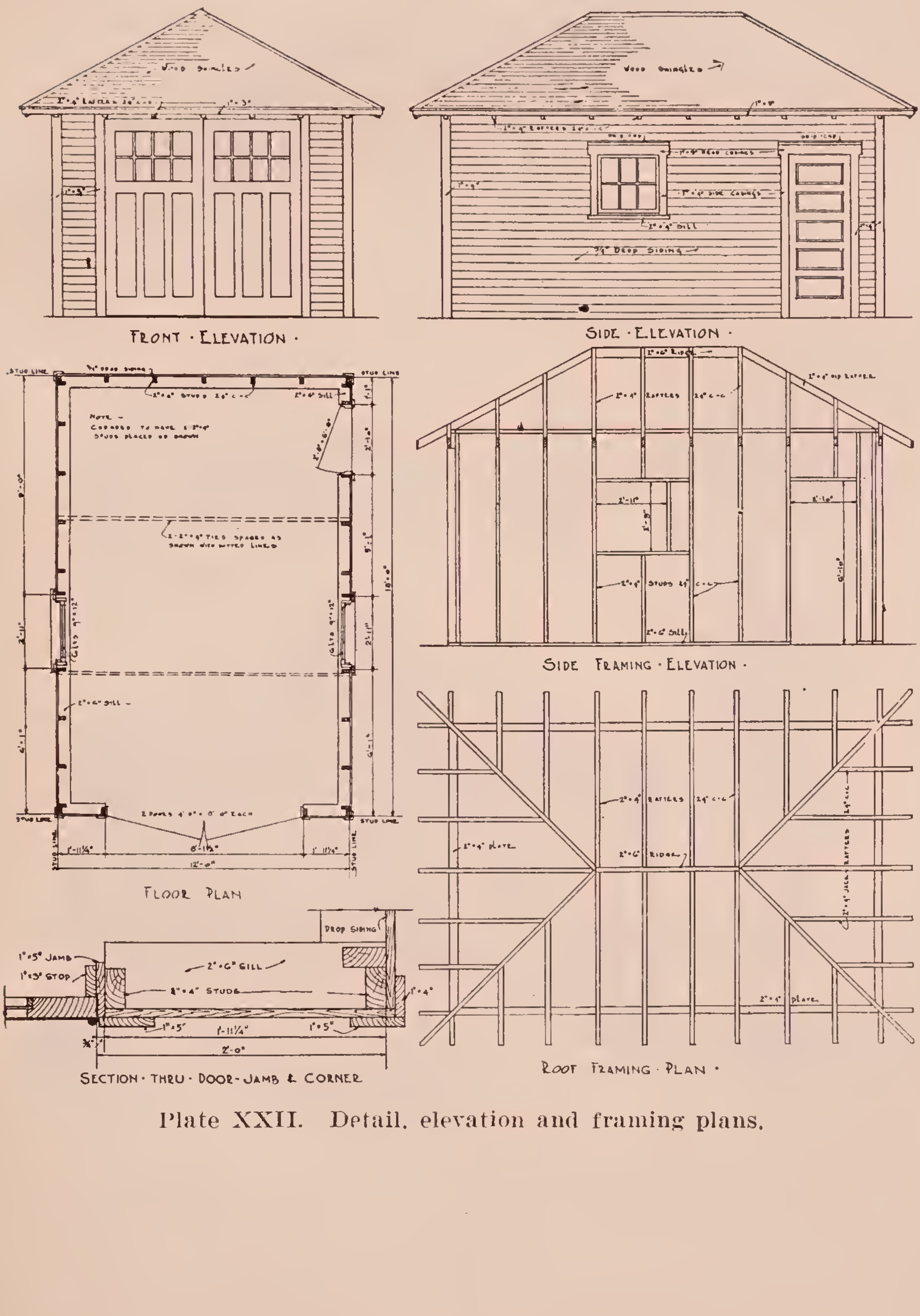


Plate XXII. Detail, elevation and framing plans.

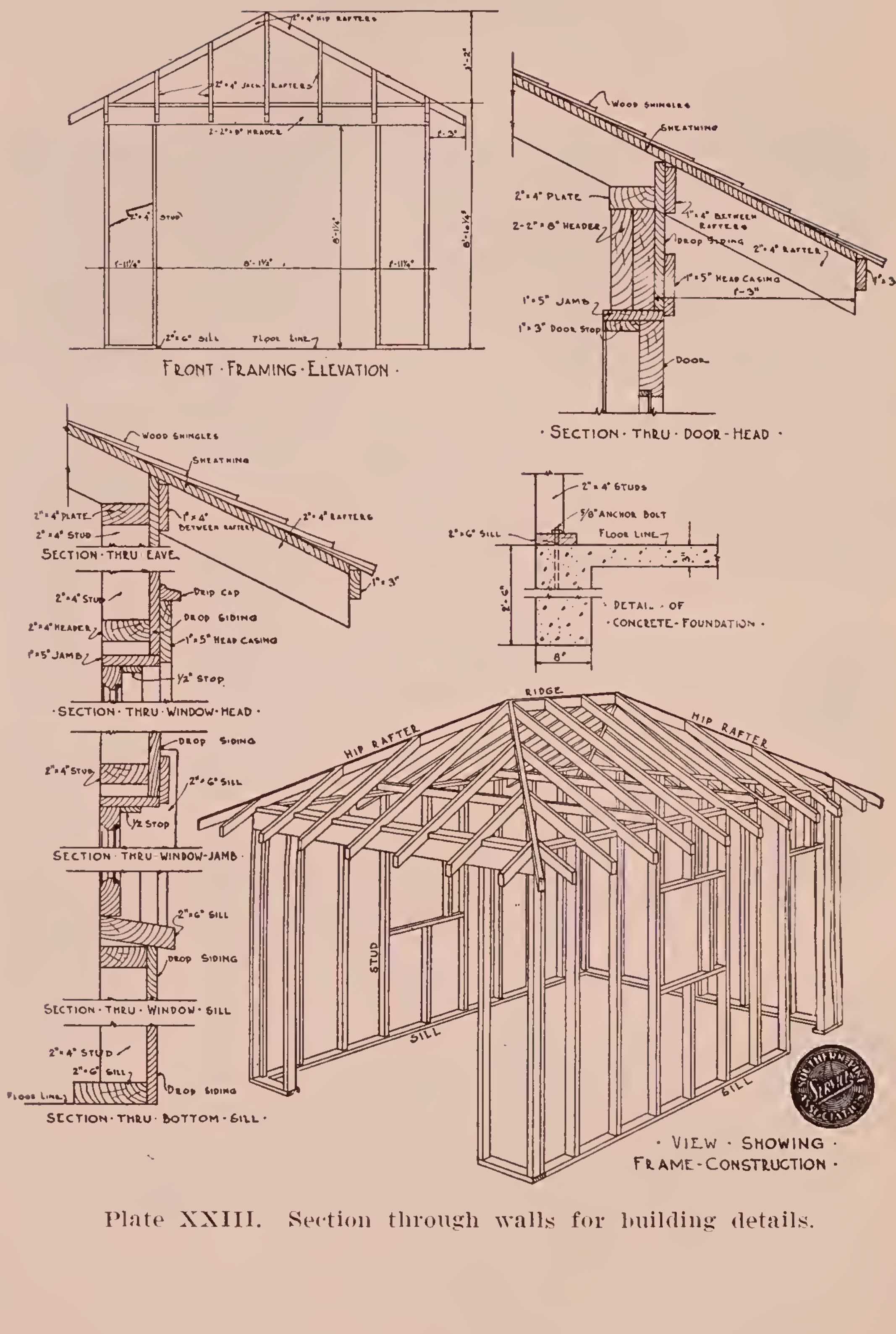


Plate XXIII. Section through walls for building details.

CHAPTER XXXVI

Building Elevations

On more complicated jobs, building elevations showing each face of the building are necessary. Churches, court-houses, and other public buildings; office buildings, apartments, etc. all require complete elevation drawings. Store plans are frequently drawn showing only front and rear elevations, while on buildings with two or more faces, identical, one elevation will suffice for all duplicates.

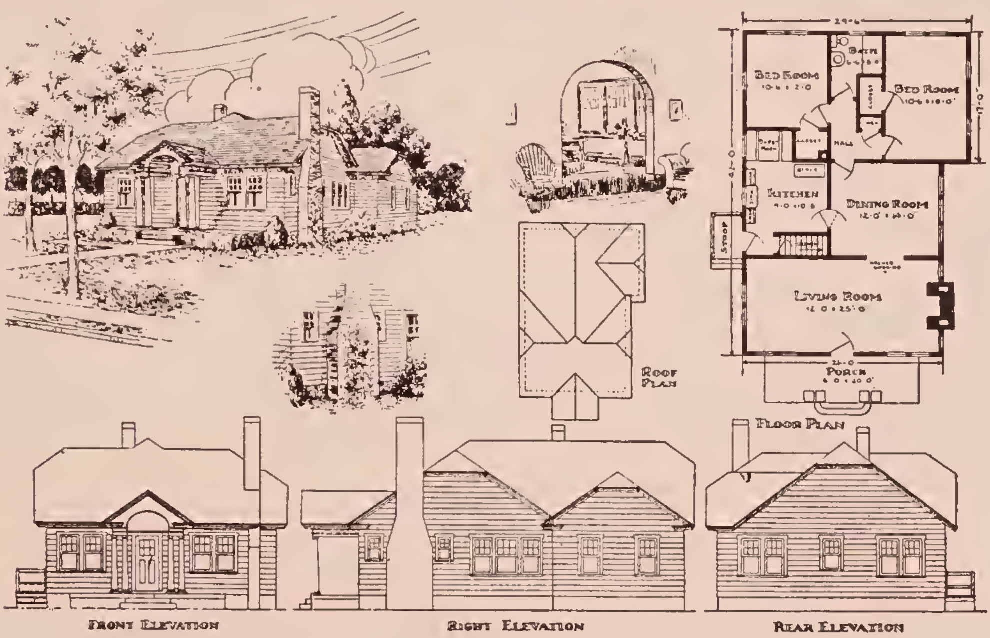


Fig. 133. Floor plan, roof plan, two sketches, three elevations and a perspective sketch of a five-room house. (From "The Builder" for March 1926. Used by permission.)

Drawing No. 47. Plan a four-room ideal bungalow and draw three elevations of same. Several sheets may be required; number extra sheets 47a, 47b, etc.

CHAPTER XXXVII

Isometric Drawing

The word "isometric" means equal measure. Isometric drawing is a type of pictorial representation based on the division of space in a plane by three lines into three equal angles of 120° each. The vertical line extends downward from the center, and becomes the height axis; one of the other lines which is at 30° to the horizontal becomes the length axis, and the third becomes the width axis. See Figure 134. When the true lengths are measured on the length axis,

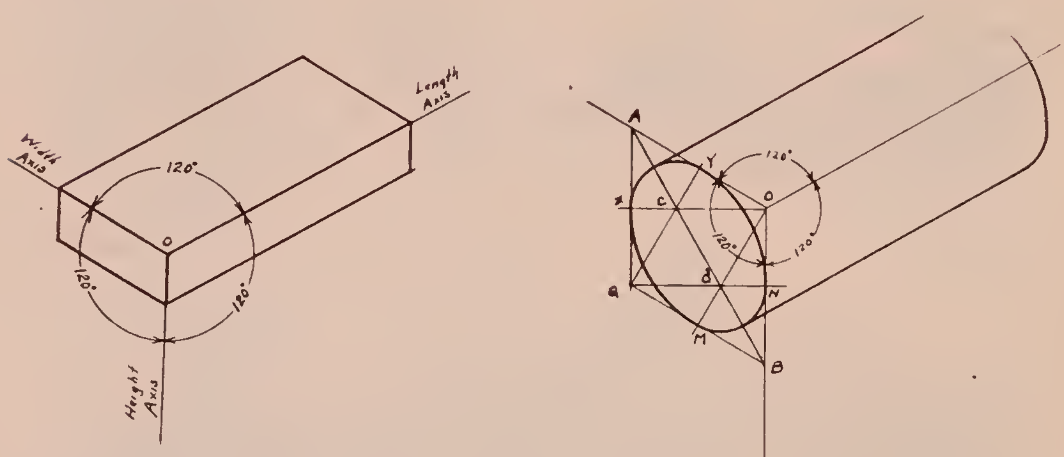


Fig. 134. Isometric drawings of a block and of a cylinder.

the object appears out of proportion. The lines of the object are drawn parallel to the axis so that an unreal picture results in that lines in a picture will not appear parallel.

The drawing of isometric circles is accomplished as follows: Draw the three axes as in the right of Figure 134. Lay off the diameter OA and OB. Draw AQ and BQ parallel to the axes. Draw OX and QN horizontal. Draw QY and OM 60° to the horizontal. AB may be drawn. The points c and d are the centers of the small arcs XY and MN. The points O and Q are the centers of the large arcs XM and YN.

Thus a circle properly foreshortened is produced. The other end of the cylinder is drawn in exactly the same way. The sides of the cylinder are drawn tangent to the circles.

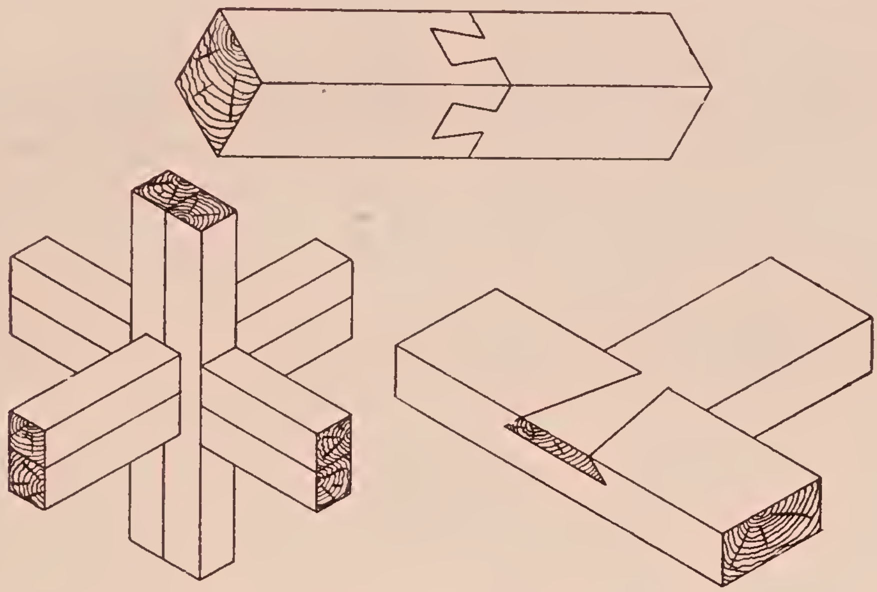


Fig. 135. Isometric drawings of puzzle joints.

Isometric drawings are used for pictorial representation because of the ease with which they may be made. They are sometimes dimensioned and used as working or shop drawings. The lines of the drawing may be shaded and the faces colored or tinted, thus producing a very attractive result.

Drawing No. 48. Draw an isometric projection of any of the problems in Plate V.

Drawing No. 49. Draw an isometric projection of one of the cylinders in Plate XI.

CHAPTER XXXVIII

Oblique Projection

In oblique projection one face of the object is drawn actual size or in scale, parallel to the vertical plane; all depth lines are then drawn at 30° or any convenient angle to the horizontal. Thus, the true shape of the object is seen in the face view and its length or width is shown in the oblique projection. In Figure 136 the end view of the hexagonal bar is drawn and its length is shown by drawing the side lines 30° to the horizontal. Frequently the face view in the ob-

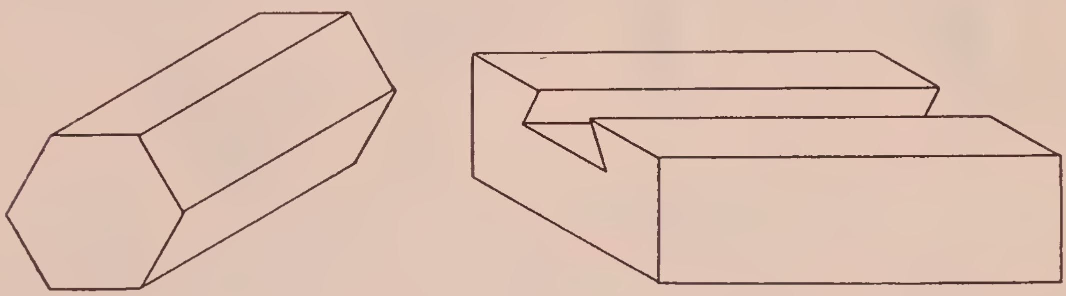


Fig. 136. Oblique projections of a hexagonal bar and a dovetail slide.

projection is the largest view of the object. (See Plate VII). Otherwise, the view which shows the greatest detail is drawn in its true shape. (See Plate V)

The drawing of circles is made very easy, providing all circles are parallel to the Vertical Plane. The circles are drawn in their true shape instead of being elliptical as in isometric drawing.

Drawing No. 50. Draw the library table in Figure 69 in oblique projection. Use a convenient scale.

CHAPTER XXXIX

Orthographic Projection of Lines and Points

Some discussion of the basic theory of mechanical drawing was included in Chapter I. The following chapters contain some of the easier abstract problems involving the principles of orthographic projection. The complete study of these principles constitutes the subject called Descriptive Geometry.

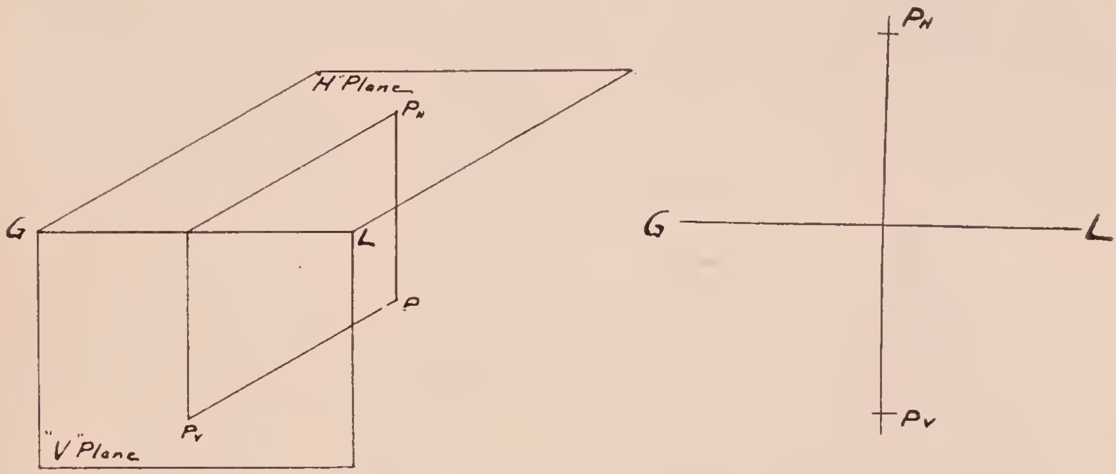


Fig. 137. A point in the third angle and the two views of the same point.

Representing a point in the third angle, we use the H plane over the point and the V plane in front of the point. (See Chapter 1.) Thus, the top view of the point is the H projection and the front view is the V projection. In the drawing, a heavy line is drawn representing the Ground Line. All H projections are shown above the Ground Line, and all V projections are shown below the Ground Line. (See Figure 137) The following rules apply.

The H and V projections of a point lie in a line perpendicular to the G. L.

The H projection is as far above the G. L. as the point

is back of V. The V projection is as far below the G. L. as the point is below H. If the point is in H or V one of its projections is in the G. L. With these rules given the following problems are to be solved:

Drawing No. 51. Draw top and front views of a 3, 4, 6, 8, or 12 sided prism, (See Chapter 46) and locate at right, the top and front views of four points in the drawing. (See

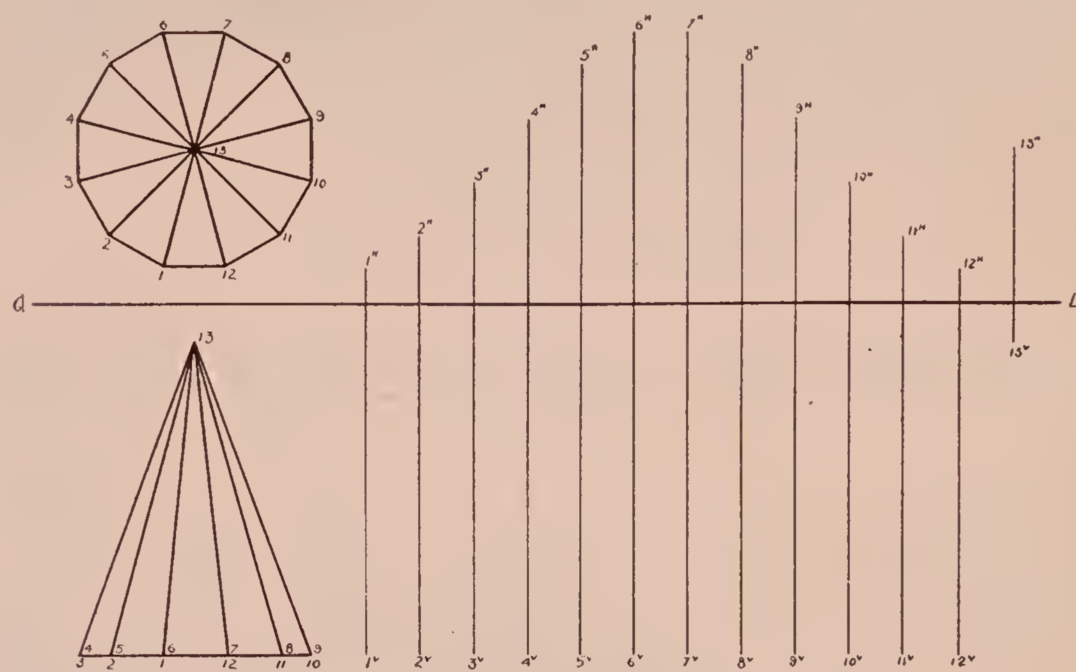


Fig. 138. Two views of points in a drawing.

Figure 138.) Space the points about ¾″ apart and also draw some of the following problems on the same sheet:

1. Draw H and V projections of a point 2″ below H and 2″ back of V.

2. Draw H and V projections of a point 3″ below H and 1″ back of V.

3. Draw H and V projections of a point 1″ below H and 3″ back of V.

4. Draw H and V projections of a point in H and 3″ back of V.

5. Draw H and V projections of a point in H and 2″ back of V.

6. Draw H and V projections of a point in the ground line.

7. Draw H and V projections of a point $\frac{1}{4}$″ below H and 3″ back of V.

Note. When designating points in the following drawings, use capital letters. For H or V projections use a sub-capital letter as shown in Figures 137 and 139. When one point in a projection covers another put the letter designating the nearest one outside the figure and the letter designating the hidden point inside the figure. See points 1 and H, Figure 140.

CHAPTER XL

Projections of Lines

The direction of a line is located by locating two points in the line. So the drawing of lines really consists in locating the end points. The following rules govern the representation of lines in orthographic projection:

1. *When a line is perpendicular to either plane, its projection on that plane is a point.* (See L K, Figure 140.) *Its projection on the other plane is perpendicular to the G. L. and shows the true length of the line.*

2. *When the line is parallel to both planes, its projections are both parallel to the G. L. and both show the true length of the line.* (Figure 139).

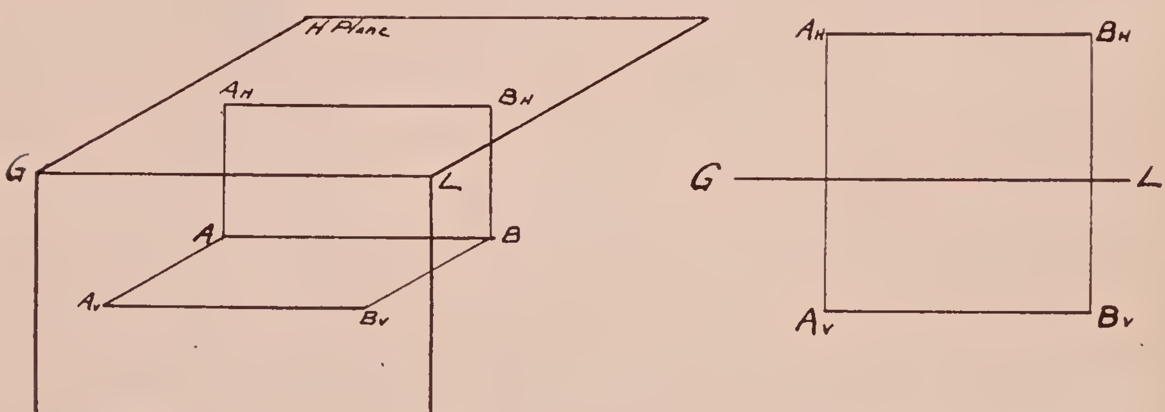


Fig. 139. Two projections of a line in the third angle with the resulting drawing of the two views.

3. *When the line is parallel to one plane but at an angle to the other, its projection on the one plane shows its true length but its projection on the other plane is foreshortened. If the line is parallel to the V plane its H projection is parallel tot he G. L.* See line A H, Figure 140.

4. *When the line is not parallel to either plane, neither*

projection is parallel to the G. L. and neither projection shows the true length. See B A, Figure 140.

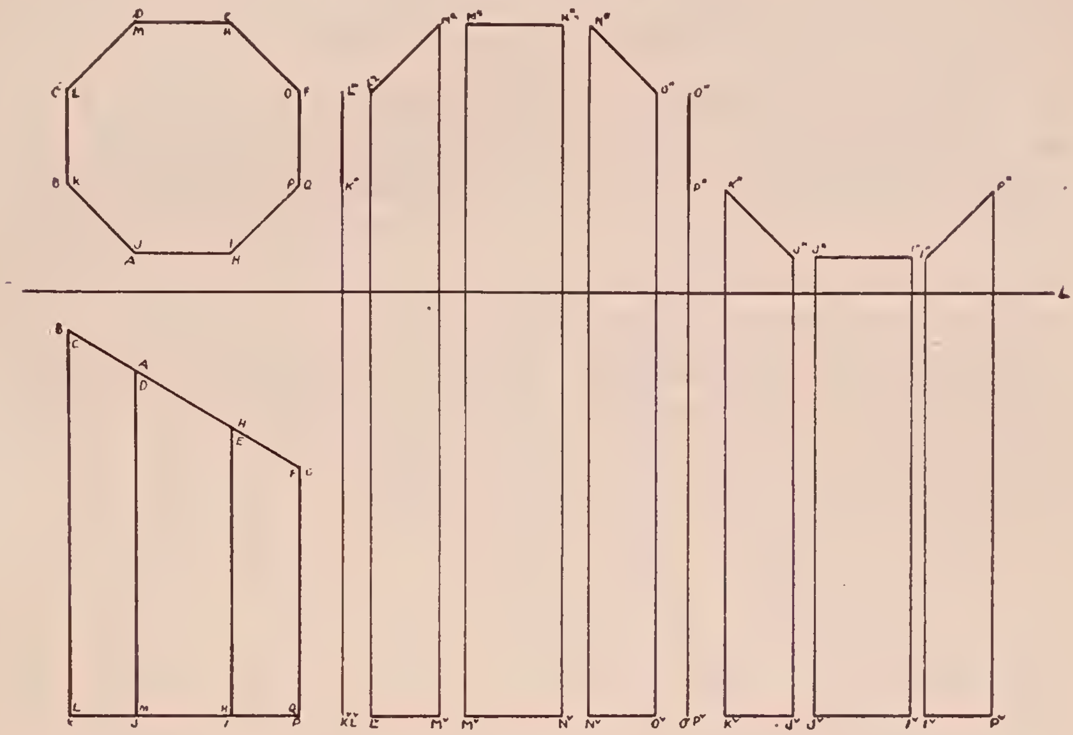


Fig. 140. Two views of lines taken from the drawing of a frustum of a prism.

Drawing No. 52. Draw top and front views of the frustum of a 4, 6, 8, or 12 sided prism of the dimensions given in top-left, Plate XXIV and fill almost all of the balance of sheet with lines taken from these views. (See Figure 140). Solve the problems given below on this sheet.

1. Draw two views of a line 1″ long parallel to H. and V, 3″ below H and 3″ back of V.

2. Draw two views of a 1½″ line 60° to H, top ½″ below H and line 2″ back of V. Line is parallel to V.

3. Draw two views of 1½″ line 45° to V, top ¾″ back of V and line 1½″ below H. Line is parallel to H.

CHAPTER XLI

True Length of Lines

When neither view or projection of a line is parallel to the ground line, neither view shows its true length. (Exception, when the line itself is perpendicular to one plane). This makes it necessary to be able to find the true length of the line when the two projections are given. We know that when one projection is parallel to the G. L., the other projection shows the true length. So by revolving either projection until it is parallel to the ground line, then determining what happens to the other, we are able to solve the problem. In Figure 141, at left, the two views of the line AB are

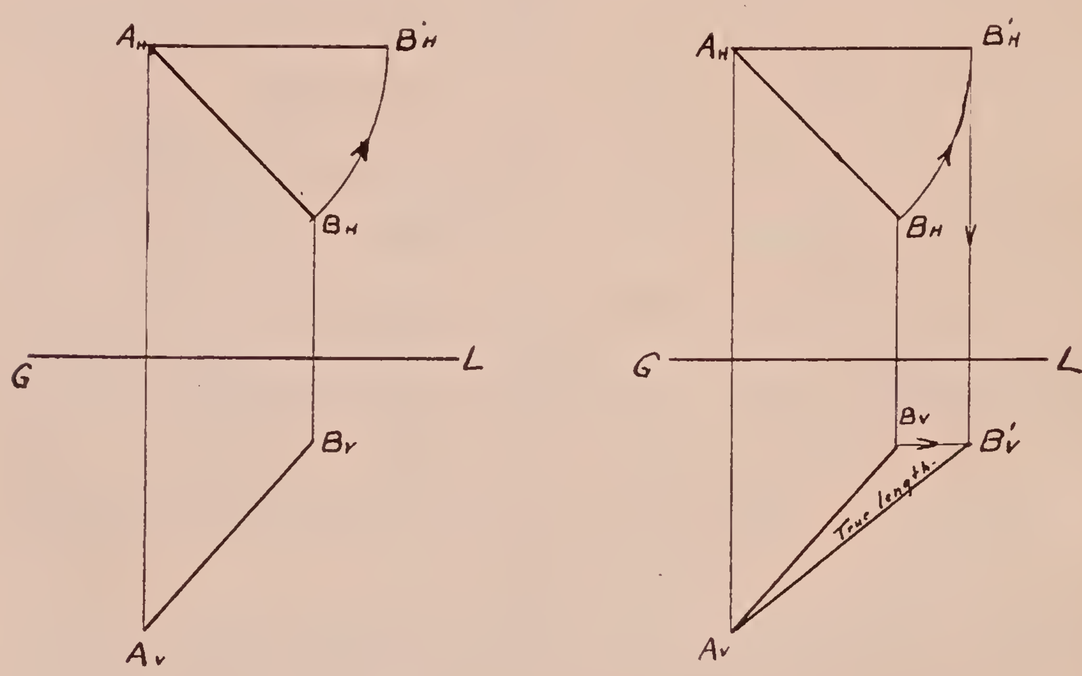


Fig. 141. Two views of a line parallel to neither plane, showing method of finding its true length.

neither one parallel to the G. L. and therefore neither view shows its true length. The H projection is revolved on Ah as a center until it becomes Ah, B'h, parallel to the G. L.

What happens to the V projection? The point B was moved parallel to the H plane when the H projection was revolved. Therefore, the V projection of the point B moves to the right, parallel to the G. L. even with B′h; so at the right, in Figure 141, we find the point B′v. Joining Av with B′v we have the true length of this line. The true length can be found by revolving either the H or V projection until it is parallel to the G. L.

Drawing No. 53. Draw 2 views of the oblique Frustum of a 3, 4, 6, 8, or 12 sided pyramid given in top left of Plate XXV and draw top and front views of any five lines (neither to show true length) and solve for true length. (See Figure 142).

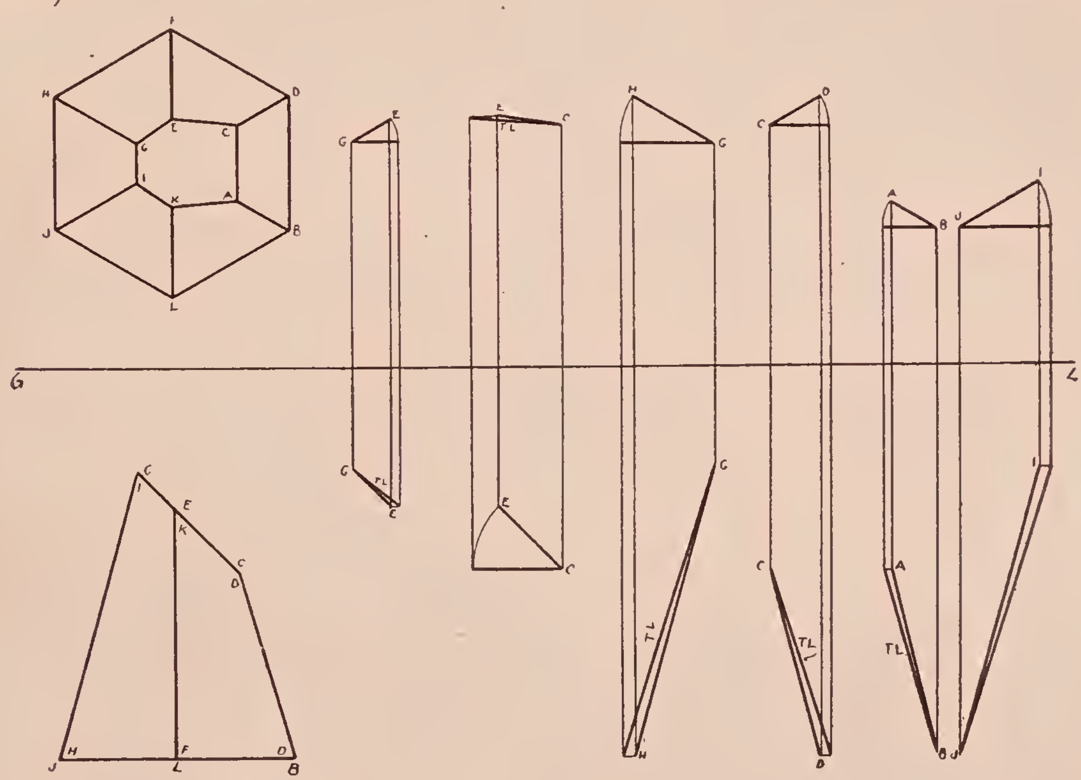


Fig. 142. A frustum of a pyramid with solution of true length of six lines.

CHAPTER XLII

Developments and Auxiliary Views

One of the most practical branches of this type of drawing is the development of surfaces. The Sheet Metal worker must make a pattern by which to cut the tin for such things as buckets, measuring cups, gutters, etc. The lateral surface and ends of regular prisms and cylinders are easy to develop. But when the ends are cut off at an angle, it becomes necessary to make an auxiliary view of that surface. Figure 143 shows the solution of this problem. The auxiliary

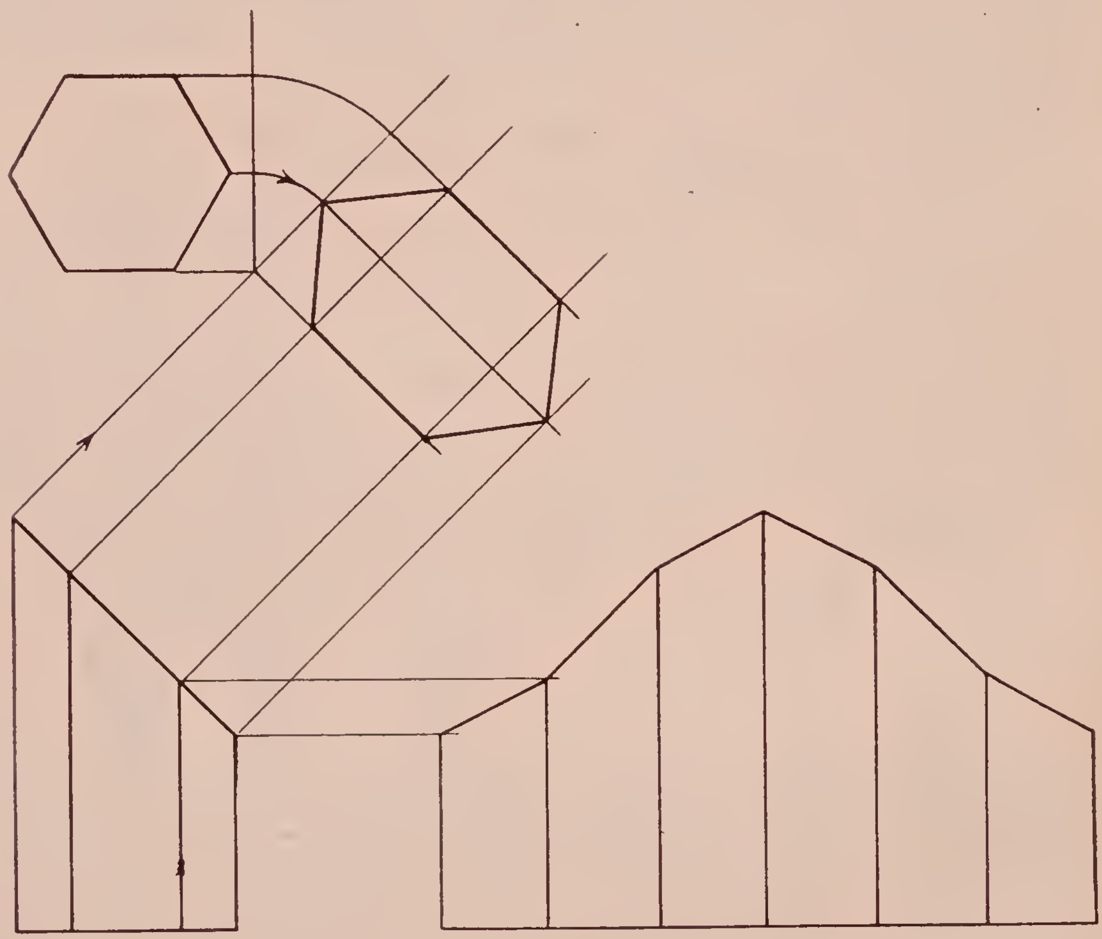


Fig. 143. Two views, auxiliary view and development, of lateral surface of frustum of prism.

view is obtained by looking perpendicularly down on the surface. The widths are obtained from the top view and the lengths from the front.

In like manner, the cylinder is developed, excepting that the circumference may be figured and measured. In Figure 144 the cylinder is 1⅞″ in diameter; its circumference is 5.49″ (See Chapter XLVIII) or approximately 5½″. The development is laid out 5½″ and this length is divided into 24 parts corresponding to the 24 parts into which the top view is divided. The auxiliary view and the lateral surface are then developed by locating 24 points and drawing the curve through them, using the irregular curve.

Drawing No. 54. Draw two views and auxiliary view and develop lateral surface of either prism in Plate XXIV.

Drawing No. 55. Draw two views and auxiliary view and develop lateral surface of either cylinder in Plate XXIV.

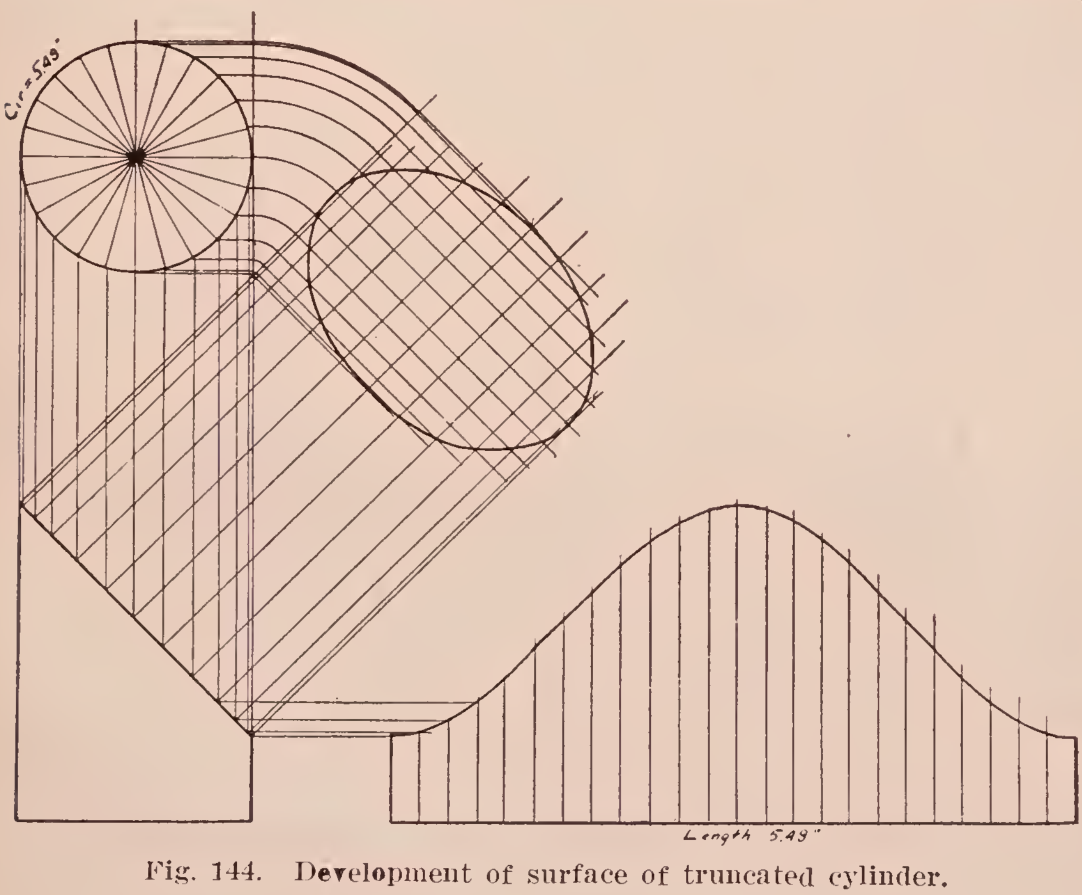


Fig. 144. Development of surface of truncated cylinder.

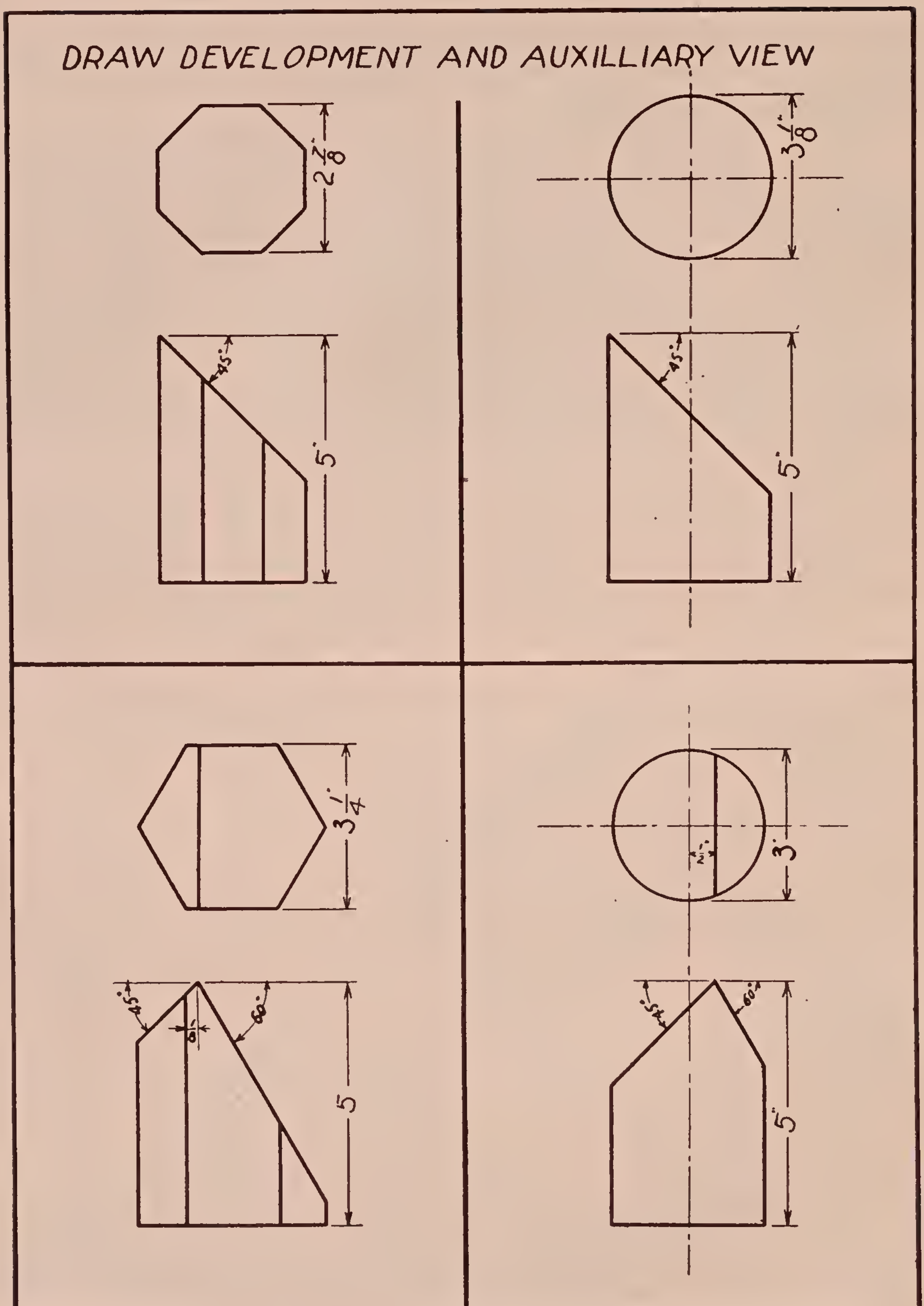


Plate XXIV. Development problems.

CHAPTER XLIII

Pyramids and Cones

The surfaces of pyramids and cones are developed by rolling them about the apex as a center. Thus, the development of a cone is a sector of a circle. By figuring the number of degrees in the sector, it can be laid out with a protractor. Figure 145 shows a cone 5″ in slant height and 2¾″ in diameter at the base. A circle AB is drawn with a radius

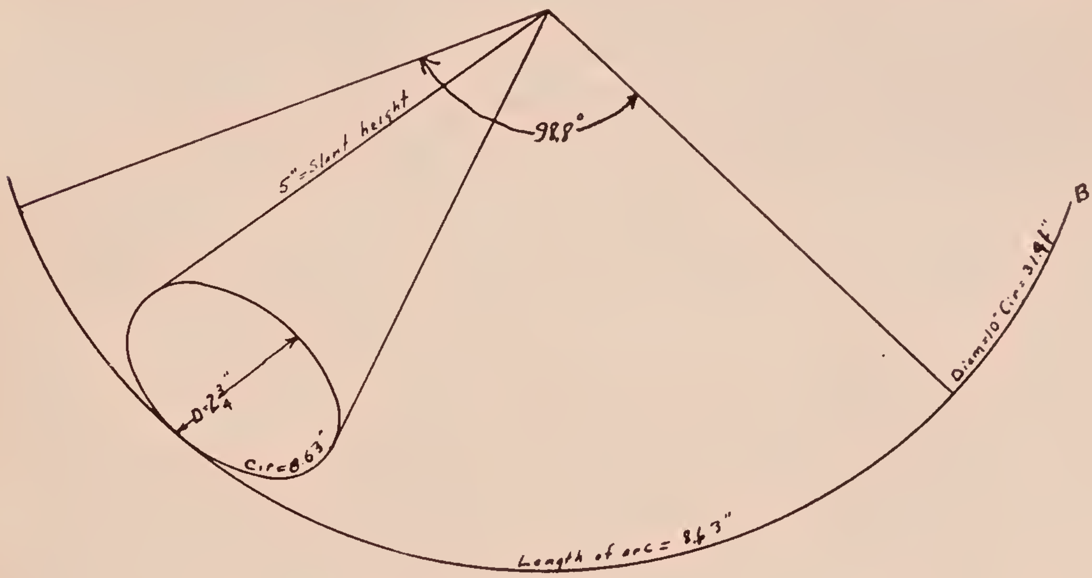


Fig. 145. Development of the surface of a cone.

equal to the slant height, 5″. On this circle the circumference of the bottom is rolled out. This is a distance of 2¾x3.1416= 8.63″. (See Chapter 48) Knowing that the large circle has a circumference of 10x3.1416 and that the arc of the development has a length of 8.63, we can find the number of degrees in the sector by taking $\frac{8.63}{31.41}$x360°. This equals 98.9°. Measure this off with the protractor.

Drawing No. 56. Draw top, front and auxiliary views and develop surface of either pyramid in Plate XXV. (See

Plate XXVI) In laying out the development, it is necessary in the lower left hand problem to find the true length of the slant height line.

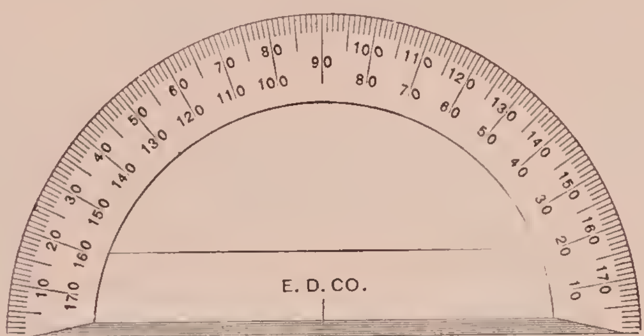


Fig. 146. A celluloid protractor for measuring angles.

Drawing No. 57. Draw top and front views and develop surface of the cone on plate XXV. Refer to Chapter 48 for circumference of circles.

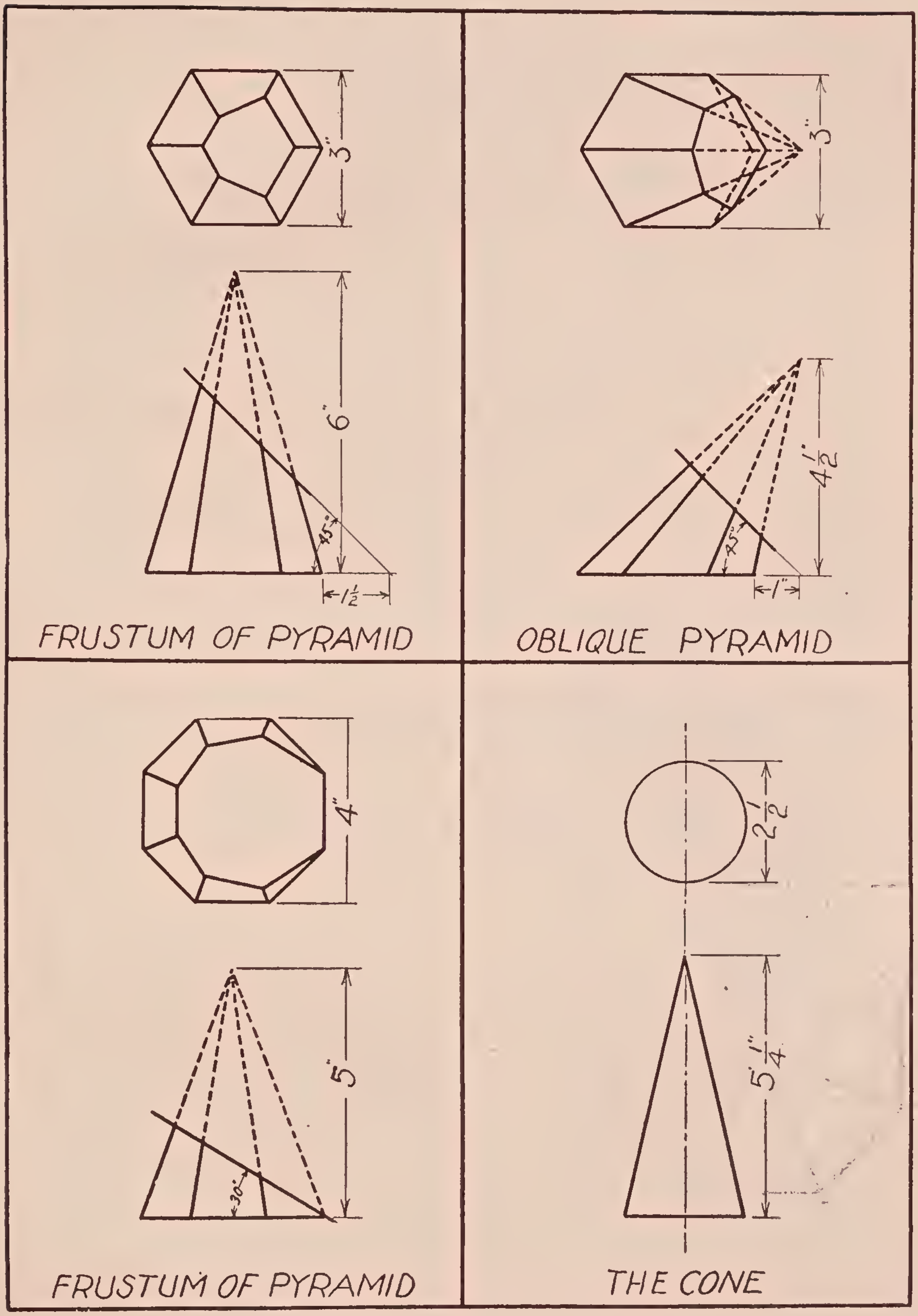


Plate XXV. Pyramids and a cone.

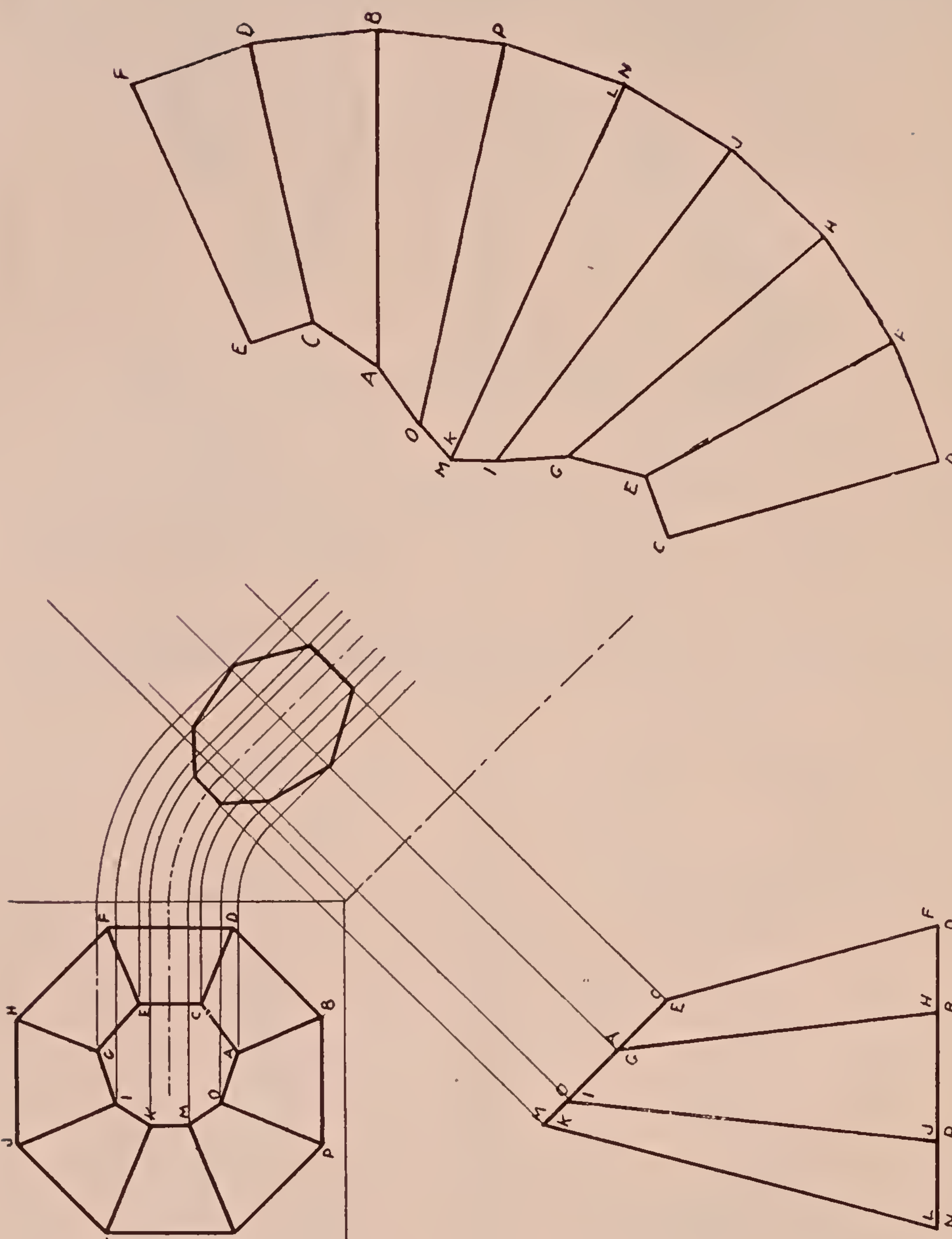


Plate XXVI. Frustum of a pyramid.

CHAPTER XLIV

Conic Sections

When a cone is cut by a plane at an angle greater than the angle of the axis with the slant height, the resulting curve is an ellipse.

When a cone is cut by a plane parallel with the slant height, the resulting curve is a parabola.

When a cone is cut by a plane which is parallel to the axis, the resulting curve is a hyperbola.

When a cone is cut by a plane perpendiuclar to the axis, the resulting curve is a circle.

The plotting of these curves and developments is done by dividing the top view into twelve or twenty-four equal parts and drawing corresponding elements in the front view. All lengths may be secured on these elements. (See Plate XXVIII.)

Drawing No. 58. Draw complete development including auxilliary view of ellipitical section of cone, Plate XXVII. (See Plate XXVIII).

Drawing No. 59. Draw either hyperbola or parabola given on Plate XXVII. Draw complete development.

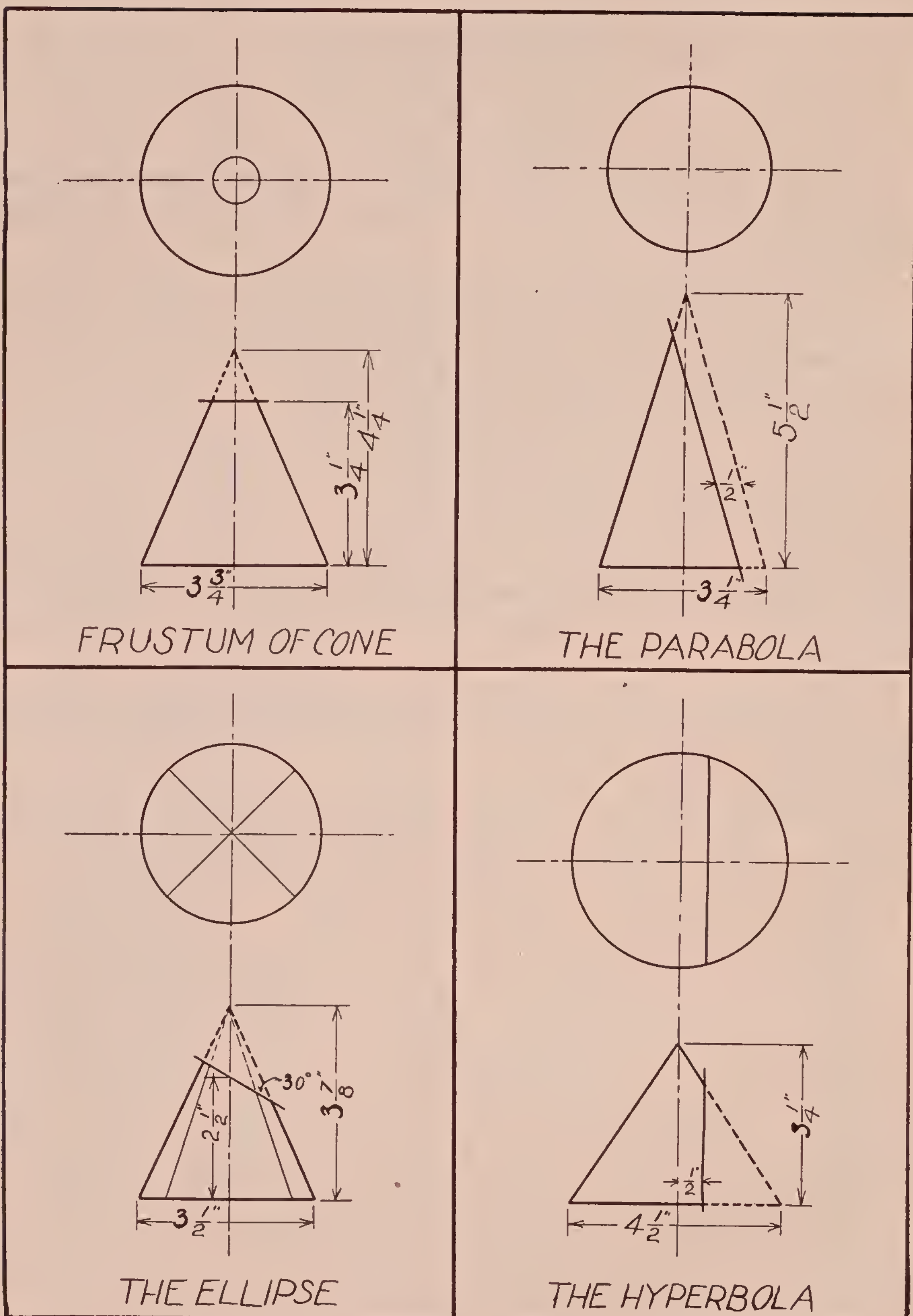


Plate XXII. Conic sections.

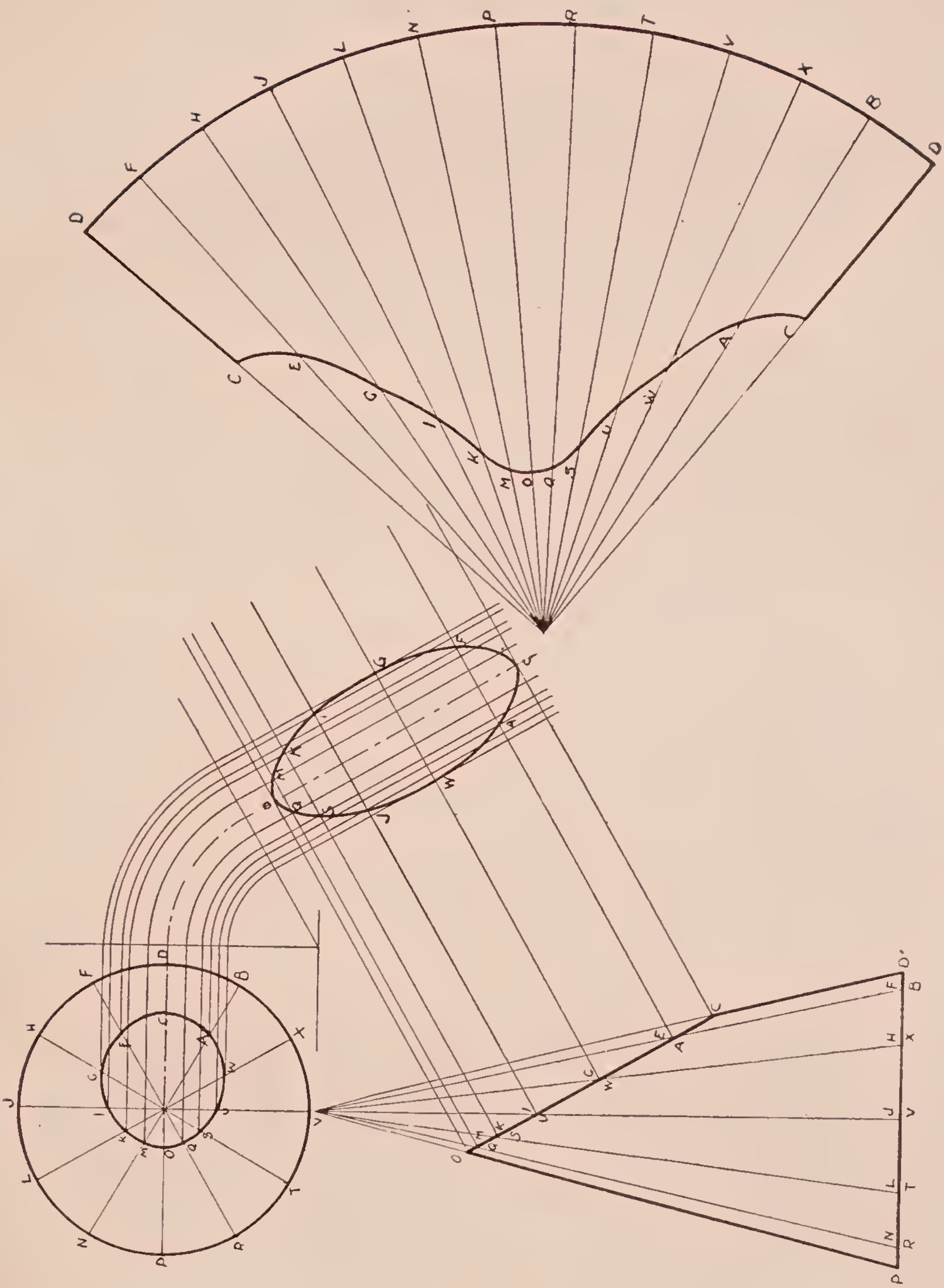


Plate XXVIII. Development of Truncated cone.

CHAPTER XLV

Intersections

Many problems result from two similar or unlike parts intersecting. The funnel shows two cones intersecting; the quart measure shows two cones. The three or four part elbow shows several frustums of cylinders. A reducing ell may show cylinders and cones intersecting. Thus, the problem of development of surfaces is readily applicable to real shop work.

When geometrical forms intersect, it is usually necessary to first develop the line of intersection; then from that, the lengths of the development may be figured. The following problems are given without solutions. If help is needed, refer to more advanced texts.

Drawing No. 60. Makes complete drawing of Problem I, Plate XXIX.

Drawing No. 61. Make complete drawing of Problem II, Plate XXIX.

Drawing No. 62. Make complete drawing of Problem III, Plate XXIX.

Drawing No. 63. Make complete drawing of Problem IV, Plate XXIX.

Drawing No. 64. Make complete drawing of Problem I, Plate XXX.

Drawing No. 65. Make complete drawing of Problem II, Plate XXX.

Drawing No. 66. Make complete drawing of Problem III, Plate XXX.

Drawing No. 67. Make complete drawing of Problem IV, Plate XXX.

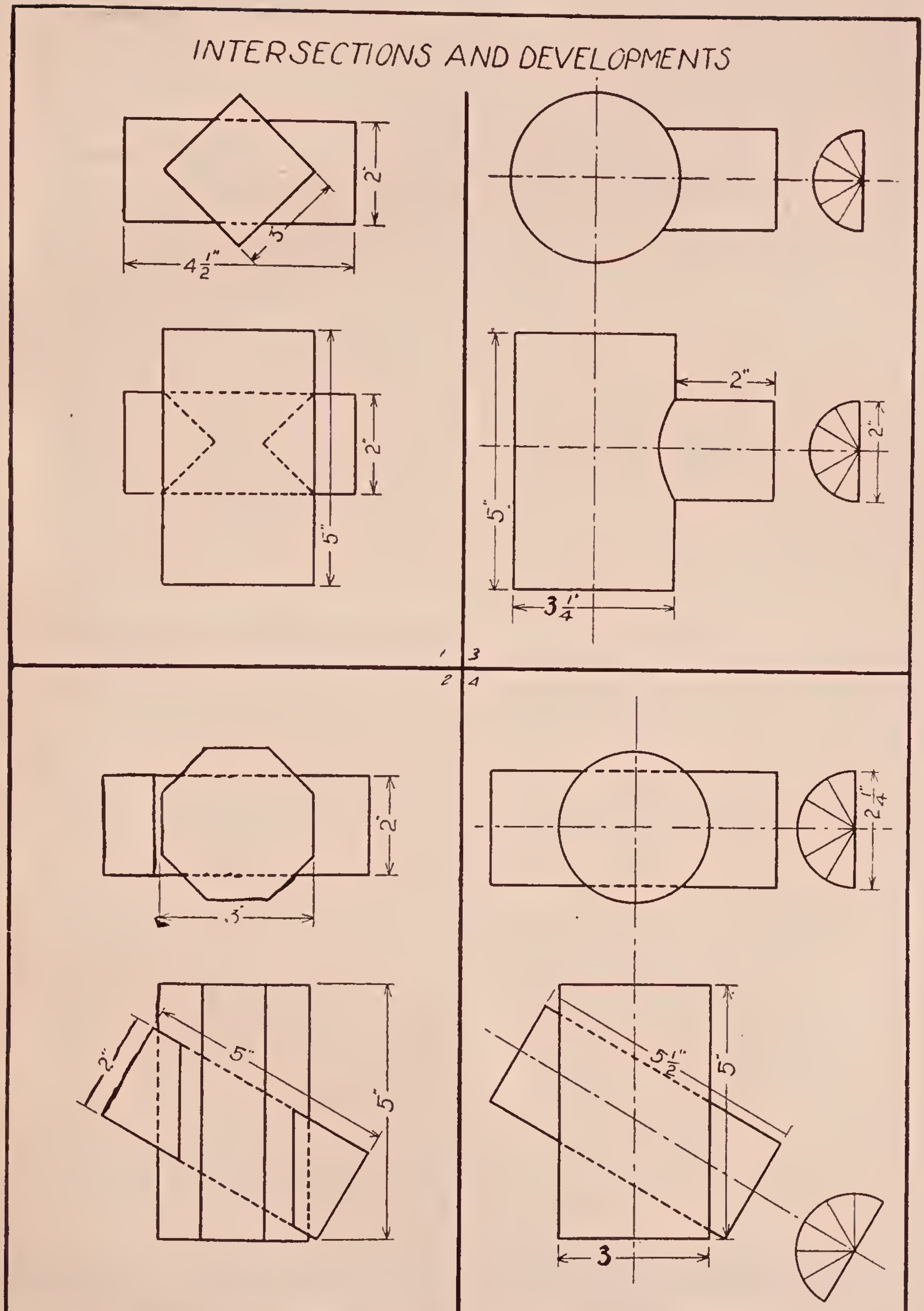


Plate No. XXIX.

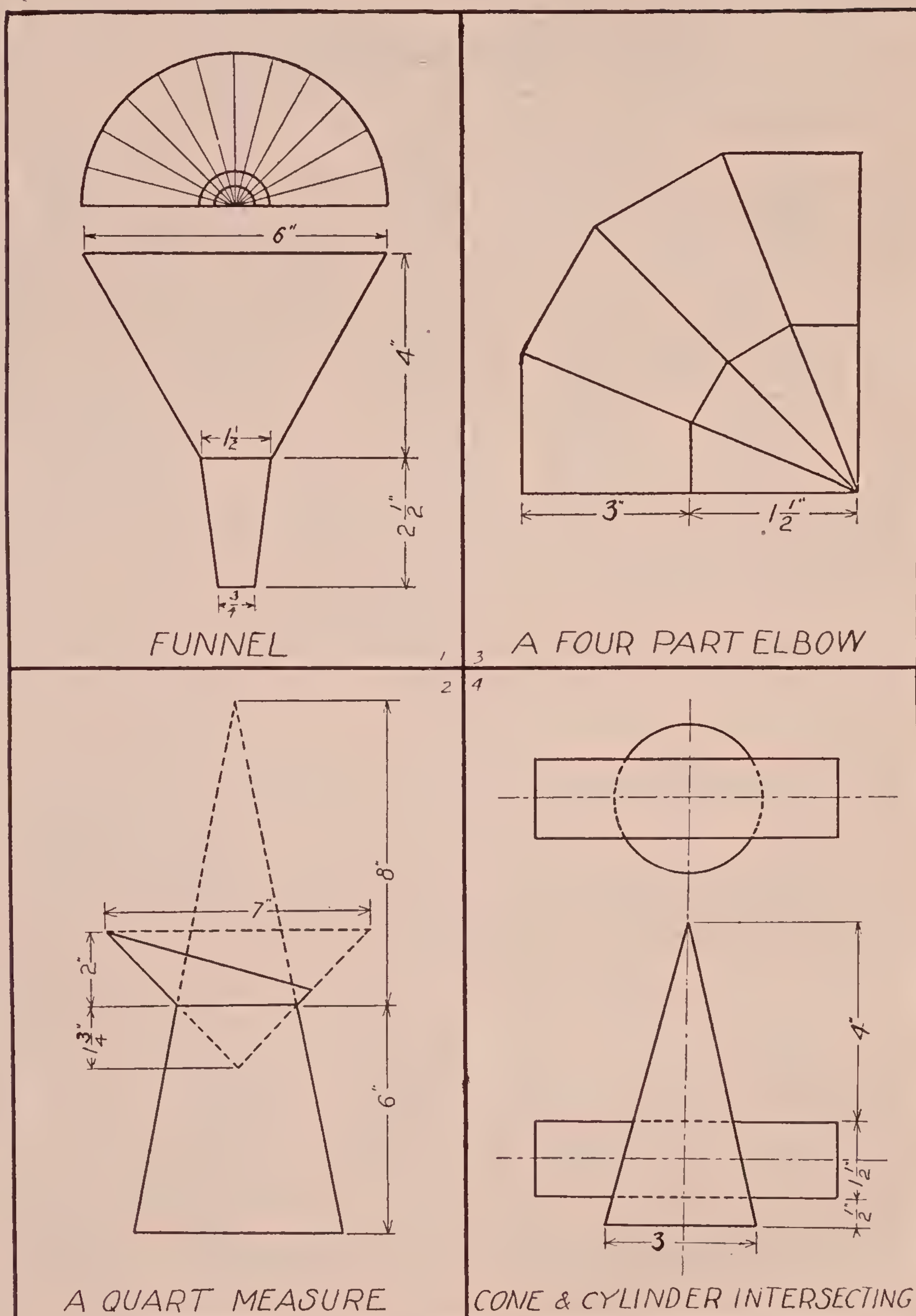

6"
4"
1½"
2½"
¾
FUNNEL
3"
1½"
A FOUR PART ELBOW
1
3
2
4
8"
7"
2"
1¾"
6"
A QUART MEASURE
4"
½"
½"
3
CONE & CYLINDER INTERSECTING

Plate No. XXX

CHAPTER XLVI

Gymnastics of Mechanical Drawing

The following problems or tricks which may be worked out with the triangles and tee square are well worth knowing. They might be called "Tricks of the Trade." The arrows on the lines indicate the direction of the drawing of the lines. The given line is always labeled A-B.

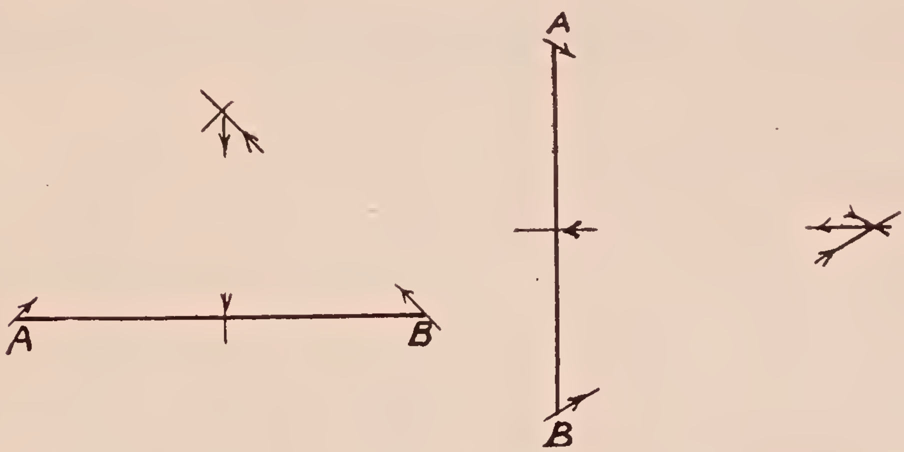


Fig. 147. To bisect a vertical or horizontal line using a triangle.

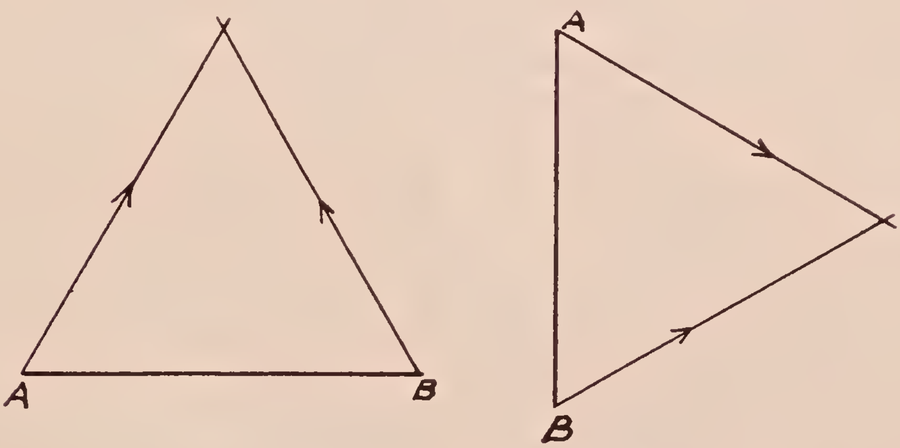


Fig. 148. To draw an equilateral triangle having base AB given, horizontal or vertical.

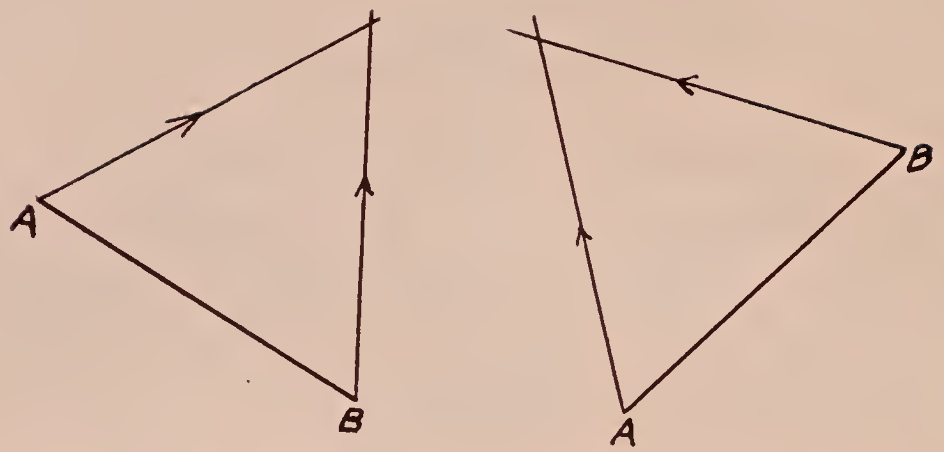


Fig. 149. To draw an equilateral triangle having base AB given at 15, 30, 45, or 60° to horizontal.

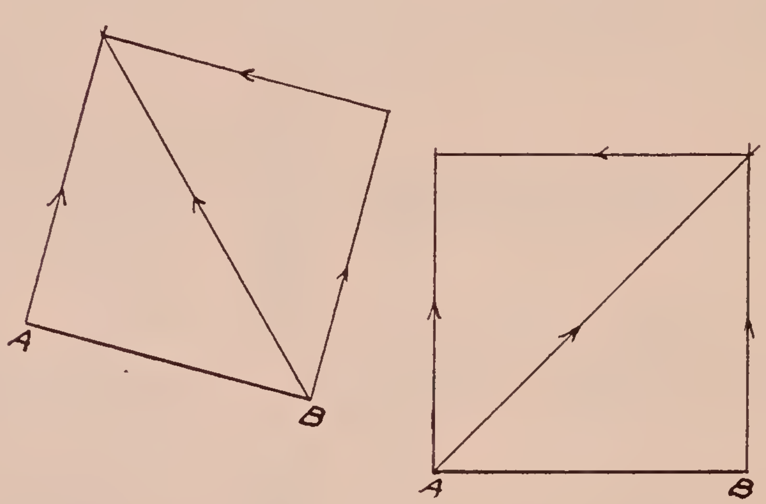


Fig. 150. To draw a square having base AB given horizontal, vertical or 15, 30, 45, 60, 75° to horizontal.

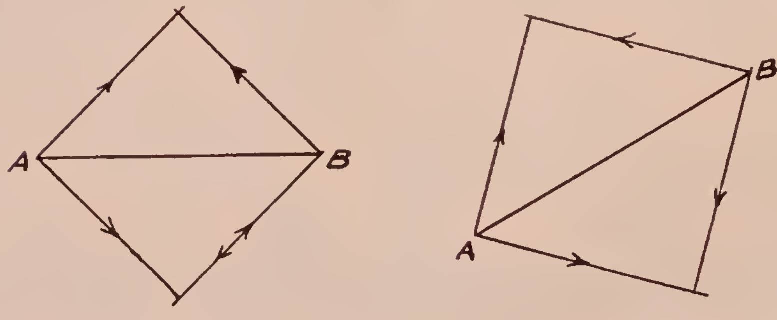


Fig. 151. To draw a square having given the diagonal AB, horizontal, vertical, or 15, 30, 45, 60, or 75° to horizontal.

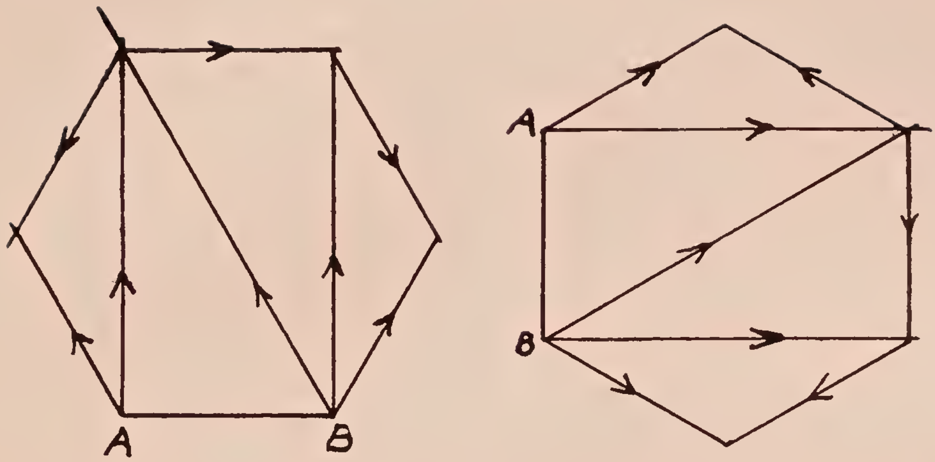


Fig. 152. To draw a hexagon with base AB given either horizontal or vertical. (First method.)

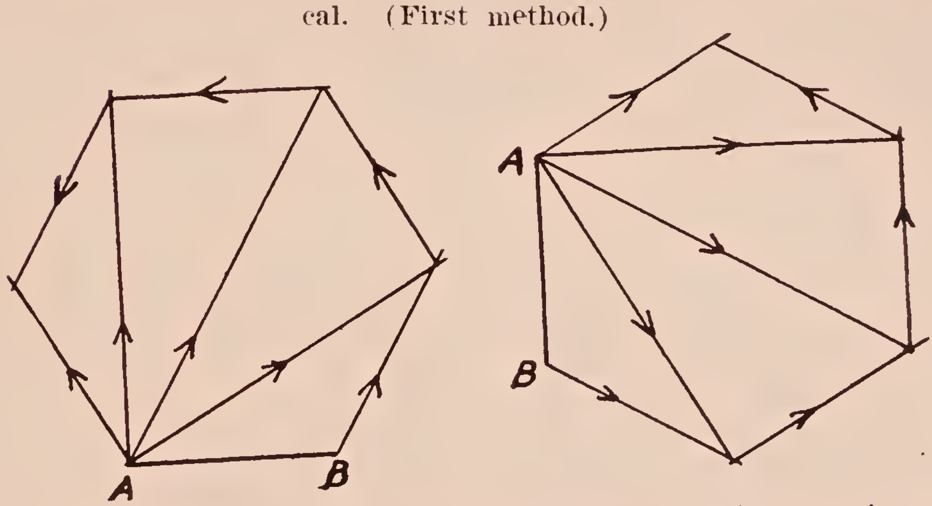


Fig. 153. To draw a hexagon having base AB given either horizontal or vertical. (Second method.)

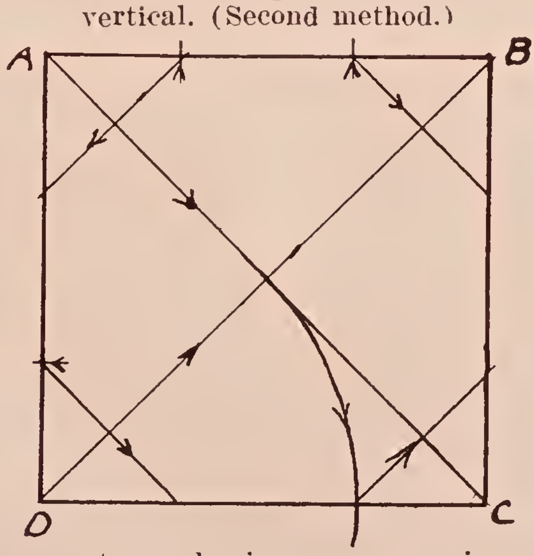


Fig. 154. To draw an octagon having a square given. (Use a compass.)

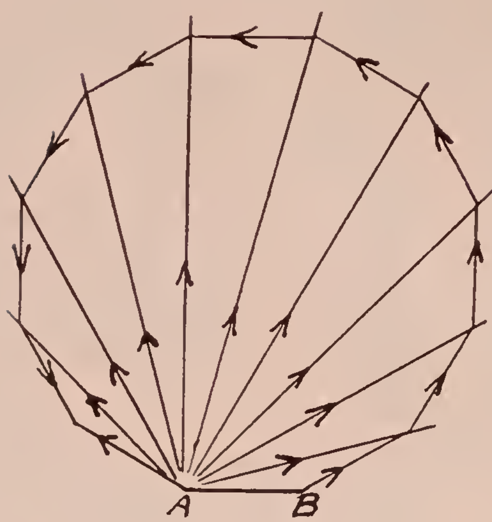


Fig. 155. To draw a twelve sided figure with base AB given. (Lines are 15° apart.)

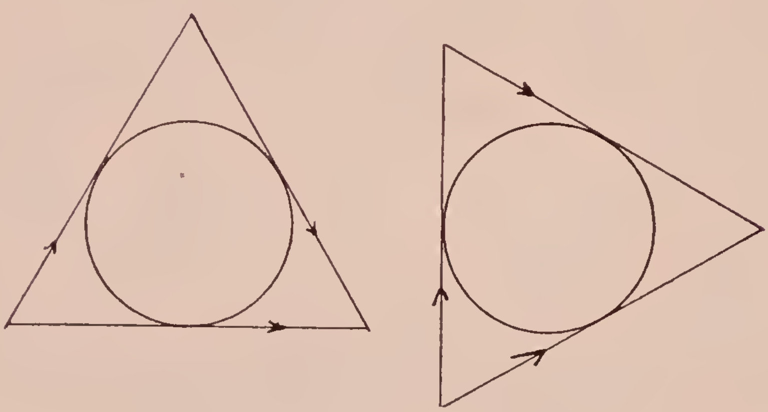


Fig. 156. To draw equilateral triangles outside a circle.

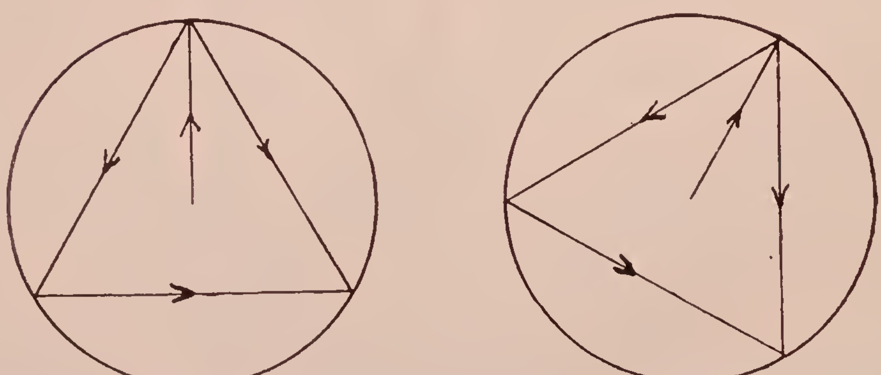


Fig. 157. To draw equilateral triangles inside a circle.

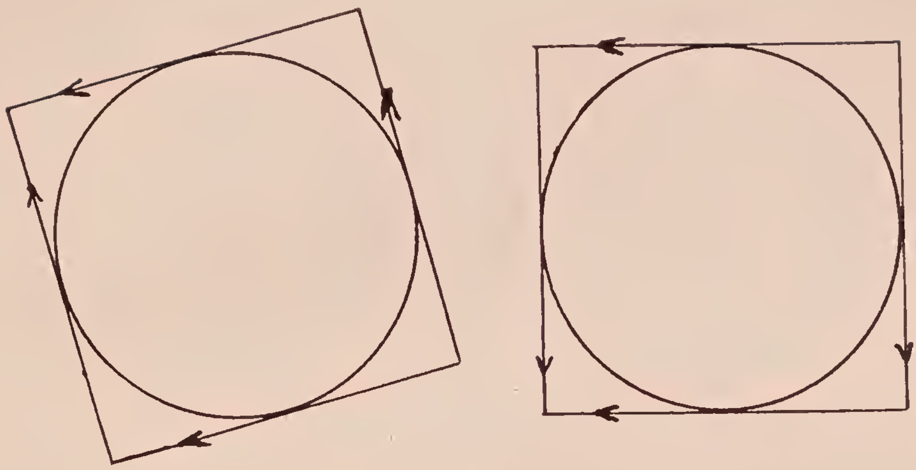


Fig. 158. To draw squares outside circles.

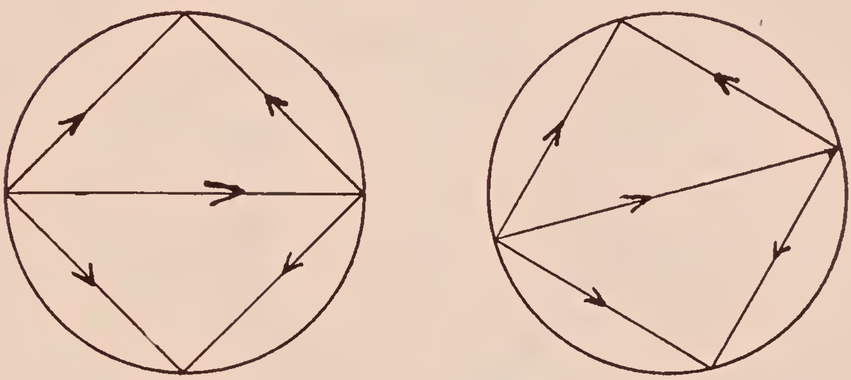


Fig. 159. To draw squares inside circles.

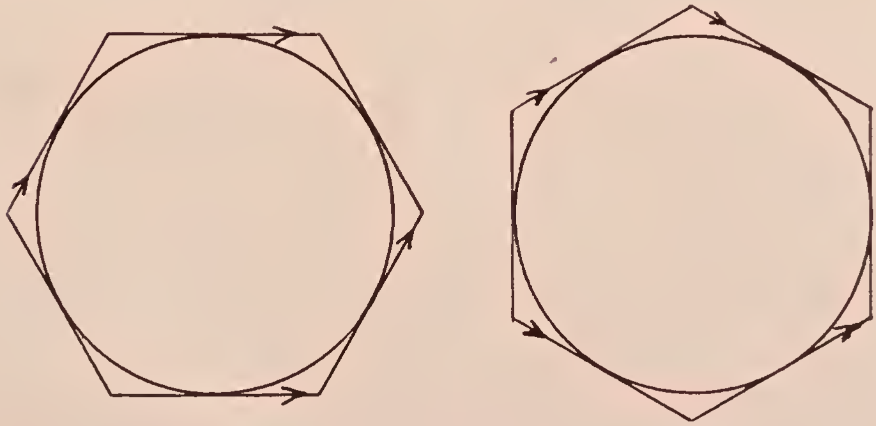


Fig. 160. To draw hexagons outside circles.

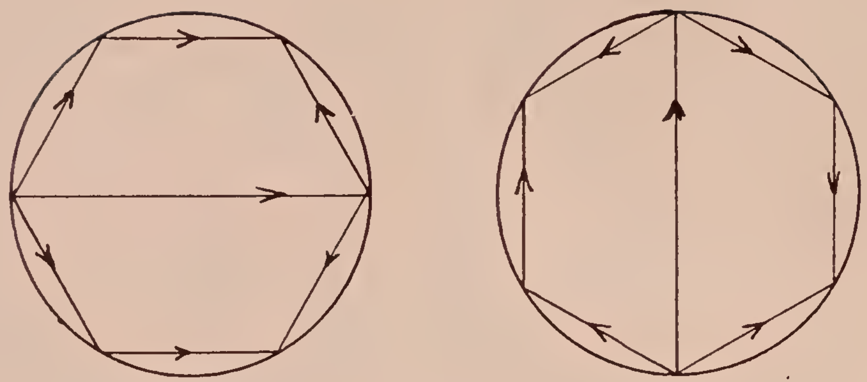


Fig. 161. To draw hexagons inside circles.

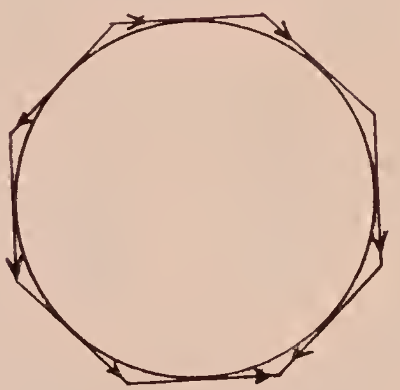


Fig. 162. To draw an octagon outside a circle.

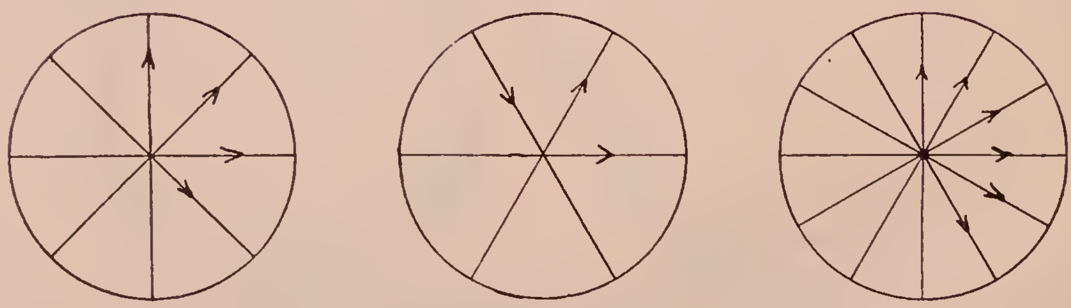


Fig. 163. To divide a circle into 6, 8, or 12 equal parts.

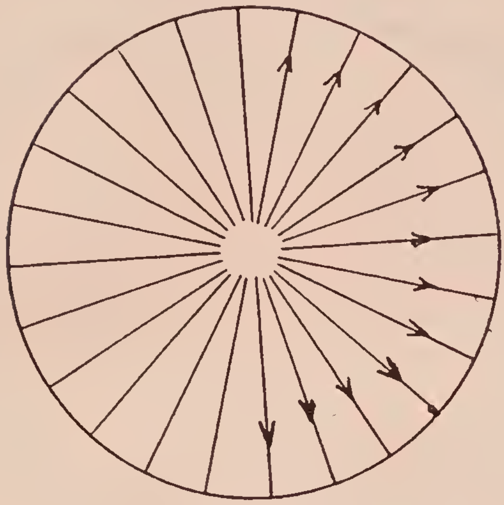


Fig. 164. To divide a circle into 24 equal parts. (Combine triangles to obtain 15° angles.)

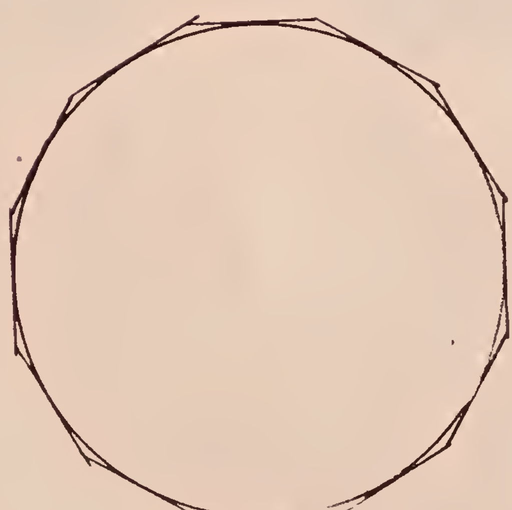


Fig. 165. To draw a 12 side figure or dodecagon outside a circle.

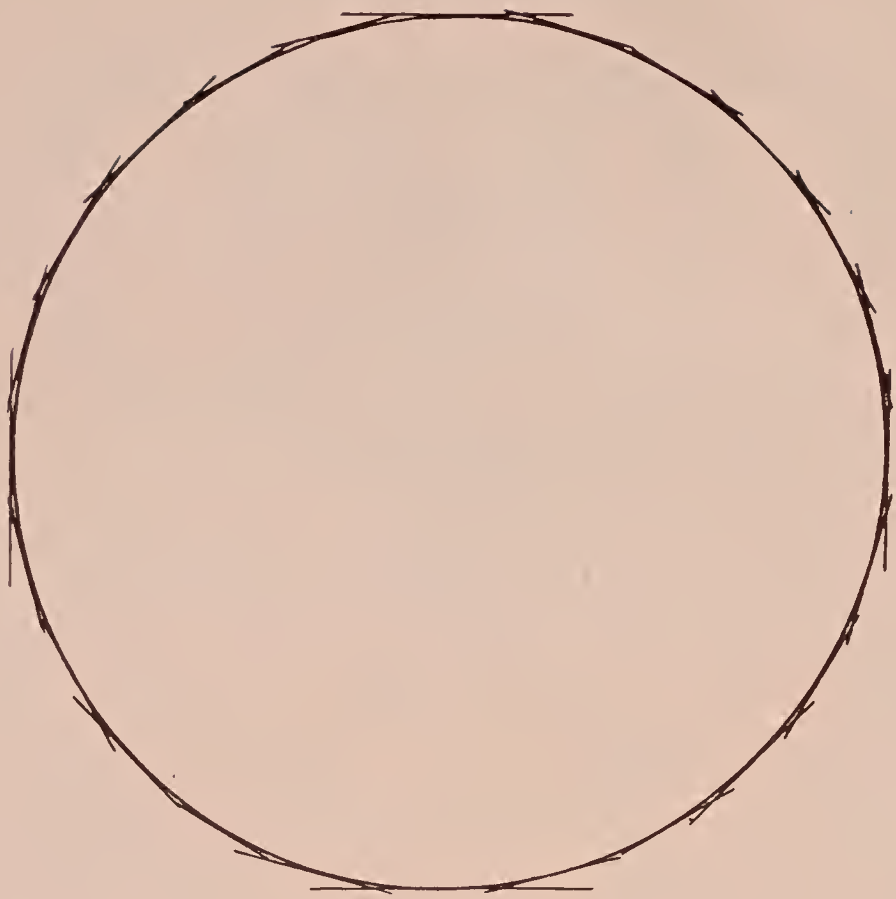


Fig. 166. To draw a 24 sided figure outside a circle. (Draw every possible tangent using both triangles separately and in combination.)

CHAPTER XLVII

Drawing Room Equipment

The drafting room should if possible have north light. If a building can be planned to include north wall light and light from the north through a saw-toothed roof construction, the light will be ideal. Drawing tables should be placed so that the greater part of the light comes from the left-front. If this is impossible, with the natural lighting of the room, an individual electric light should be provided for each desk. Light coming from two sides must be at left of and in front

Fig. 167. An ideal drawing desk for a public school drafting room.

of the draftsman. This may be injurious to the eyes, but it is necessary for good work. Eye shades may be worn if it is found advisable.

Individual storage drawers and drawing boards constitute the ideal drawing room arrangement. (See Figure 167.) The drawings are kept on the board until completed; then

they are turned in to the teacher. No drawing paper should be rolled. The teacher should keep the sheet paper and issue it as needed, to prevent its being rolled and stored in the small tool drawer.

For the smaller school, a table similar to Figure 168 is recommended. A separate board is kept on this table, but at the end of each period the student removes his paper and stores it together with his other supplies in a portfolio similar to that shown in Figure 20. These portfolios may be kept by the instructor in a storage case having one drawer for each section or class.

Fig. 168. A good type of drawing table for Junior High School classes.

When drawing instruments are furnished, it seems best to buy enough moderately priced sets to issue one to each pupil, who is charged with it and perhaps makes a deposit guaranteeing its safe return. This centralizes the responsibility of its loss or damage to the one student.

The drawing room must be equipped with a blue-print frame and a wash basin. Some blackboard space is desirable. Also, a bulletin and exhibit space is very desirable. Good drawings should be exhibited on this space. A very fine ex-

ample of a combination of blackboard and bulletin board may be seen in the Tulsa, Oklahoma, high school shops. It is shown in Figure 169. Many things may be tacked on such a bulletin space, such as drawings from catalogs, tables, maps, pictures, and other helpful or inspirational material.

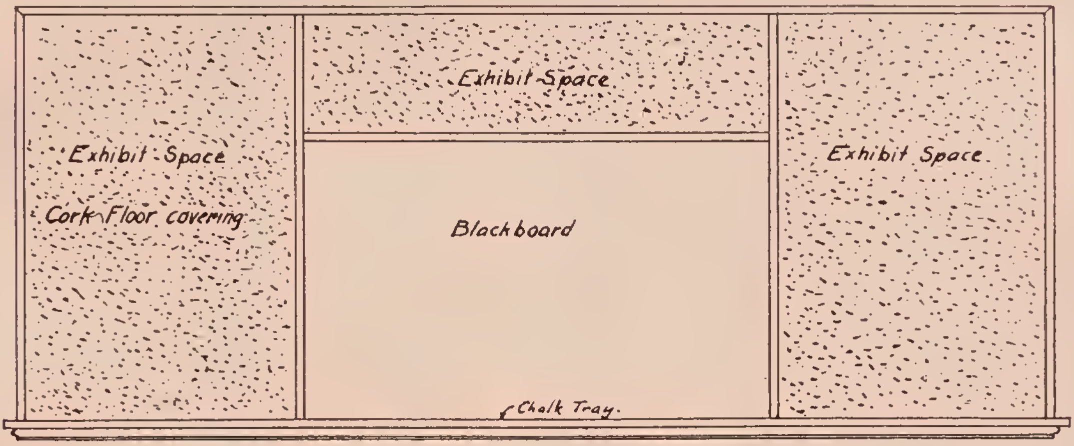


Fig. 169. Blackboard and exhibit board combination in Tulsa, Oklahoma, High School shops.

CHAPTER XXXXIV

Useful Tables

Circumference of Circles

Diameter in Inches	Circumference, Inches	Diameter in Inches	Circumference, Inches
1½	4.7124	6¾	21.205
1⅝	5.1051	6⅞	21.598
1¾	5.4978		
1⅞	5.8905	7	21.991
		7⅛	22.383
2	6.2832	7¼	22.776
2⅛	6.6759	7⅜	23.169
2¼	7.0686	7½	23.562
2⅜	7.4613	7⅝	23.954
2½	7.8540	7¾	24.347
2⅝	8.2467	7⅞	24.740
2¾	8.6394		
2⅞	9.0321	8	25.132
		8⅛	25.525
3	9.4248	8¼	25.918
3⅛	9.8175	8⅜	26.310
3¼	10.210	8½	26.703
3⅜	10.602	8⅝	27.096
3½	10.995	8¾	27.489
3⅝	11.388	8⅞	27.881
3¾	11.781		
3⅞	12.173	9	28.274
		9⅛	28.667
4	12.566	9¼	29.059
4⅛	12.959	9⅜	29.452
4¼	13.351	9½	29.845
4⅜	13.744	9⅝	30.237
4½	14.137	9¾	30.630
4⅝	14.529	9⅞	31.023
4¾	14.922		
4⅞	15.315	10	31.416
		10⅛	31.808
5	15.708	10¼	32.201
5⅛	16.100	10⅜	32.594
5¼	16.493	10½	32.986
5⅜	16.886	10⅝	33.379
5½	17.278	10¾	33.772
5⅝	17.671	10⅞	34.164
5¾	18.064		
5⅞	18.457	11	34.558
		11⅛	34.950
		11¼	35.343
6	18.849	11⅜	35.735
6⅛	19.242	11½	36.128
6¼	19.635	11⅝	36.521
6⅜	20.027	11¾	36.913
6½	20.420	11⅞	37.306
6⅝	20.813		

Decimal Equivalents of Fractions

1/32	.03125	7/32	.21875	13/32	.40625	19/32	.59375	25/32	.78125	31/32	.96875
1/16	.0625	¼	.25	7/16	.4375	⅝	.625	13/16	.8125	1″	1.0000
3/32	.09375	9/32	.28125	15/32	.46875	21/32	.65625	27/32	.84375		
⅛	.125	5/16	.3125	½	.5	11/16	.6875	⅞	.875		
5/32	.15625	11/32	.34375	17/32	.53125	23/32	.71875	29/32	.90625		
3/16	.1875	⅜	.375	9/16	.5625	¾	.75	15/16	.9375		